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GEESE OF THE ANDERSON RIVER DELTA, NORTHWEST TERRITORIES

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled GEESE OF THE ANDERSON RIVER DELTA, NORTHWEST TERRITORIES submitted by THOMAS W. BARRY in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

The snow goose (Chen caerulescens), Pacific brant (Branta bernicla nigricans), and white-fronted goose (Anser albifrons) have adapted themselves to the arctic environment and to different habitat niches at the Anderson River Delta, N.W.T. The nesting season along the shores of the Arctic Ocean is short, but the geese are well adapted to it. They arrive on the nesting grounds able to nest as soon as snow conditions permit. They are already paired and have copulated. They are physiologically ready for an "average" season. In seasons later than average there is a reduction in the number of eggs laid. If conditions remain adverse for such a long time that the young would be unable to fly by fall freeze-up, the geese will not nest at all. Instead, they bypass the remaining events of the reproductive cycle and go into their annual molt early, and thus are strong flyers before fall freeze-up. As they are long-lived, they can recoup a reproductive failure in succeeding seasons.

Within the arctic environment the species of geese are adapted to microhabitats suited to their requirements for food, nesting sites, protection from predators and their general habits. These are found in zones as one either moves upstream in a river delta or from north to south in the arctic in general. The Pacific brant requires low coastal or delta islands (for protection from its main predator, the arctic fox) covered with turf (grass and sedge) which is its food and nest material.

The snow goose is a colony nester, seeking protection in numbers. Snow geese require large flat areas where they can concentrate their nests, and yet be safe from spring floods. Their food habits are more catholic than those of brant, and this allows them to occupy a larger variety of vegetative zones. The white-fronted goose is the most inland or southerly nester of the three species. White-fronts scatter their nests widely in the scrub willow of the tundra. As solitary nesters they keep family groups of prior seasons together to help distract mammalian predators from the nest. The white-front has excellent protective coloration and has evolved the habit of dispersal to escape predators.

Variable weather conditions and cyclic or unusual amounts of predation can cause large fluctuations in the numbers of geese in fall flocks. With our present knowledge and facilities it is possible to predict the trends of these population changes by early June of each nesting season.

ACKNOWLEDGEMENTS

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Introduction

The Anderson River begins its 420-mile course to the Arctic Ocean at a point approximately 20 miles north of Great Bear Lake. It has a drainage basin of about 22,000 square miles. For the lower hundred miles, from The Forks at the junction of the Anderson and Carnwath rivers, it flows generally south to north, meandering through a flood-plain occupying a broad U-shaped valley with hills rising to nearly 800 feet in places. The hills near the delta where the Anderson enters Wood Bay rise 187 feet at South Bluffs and 300 feet on Nicholson Island, which separates part of Wood Bay from Liverpool Bay. Liverpool Bay is an extension of the Beaufort Sea of the Arctic Ocean.

The flood-plain of the Anderson River varies in width from one mile to five miles at the delta. Height of the flood-plain above summertime water levels decreases from about 20 feet upstream to only one foot or less in the delta. Figures 1 and 2 show the lower portions of the Anderson River and the delta where this study was conducted.

It is in the protection of the Anderson River valley that trees, spruce, birch, poplar, and tamarack, reach their northernmost limits. Similarly, many other species of plants and animals are found at the northern extremities of their range. The treeless part of the river valley, which forms a large part of the delta, is of course strongly influenced by the Arctic Ocean and its ice. This band of tundra, part of the Arctic Coastal Plain, is described in the Pilot of Arctic Canada (Mines and Technical Surveys, 1959). This low rolling country, with its mass of lakes, mostly poorly drained, is underlain with glacial till (Mackay, 1958).

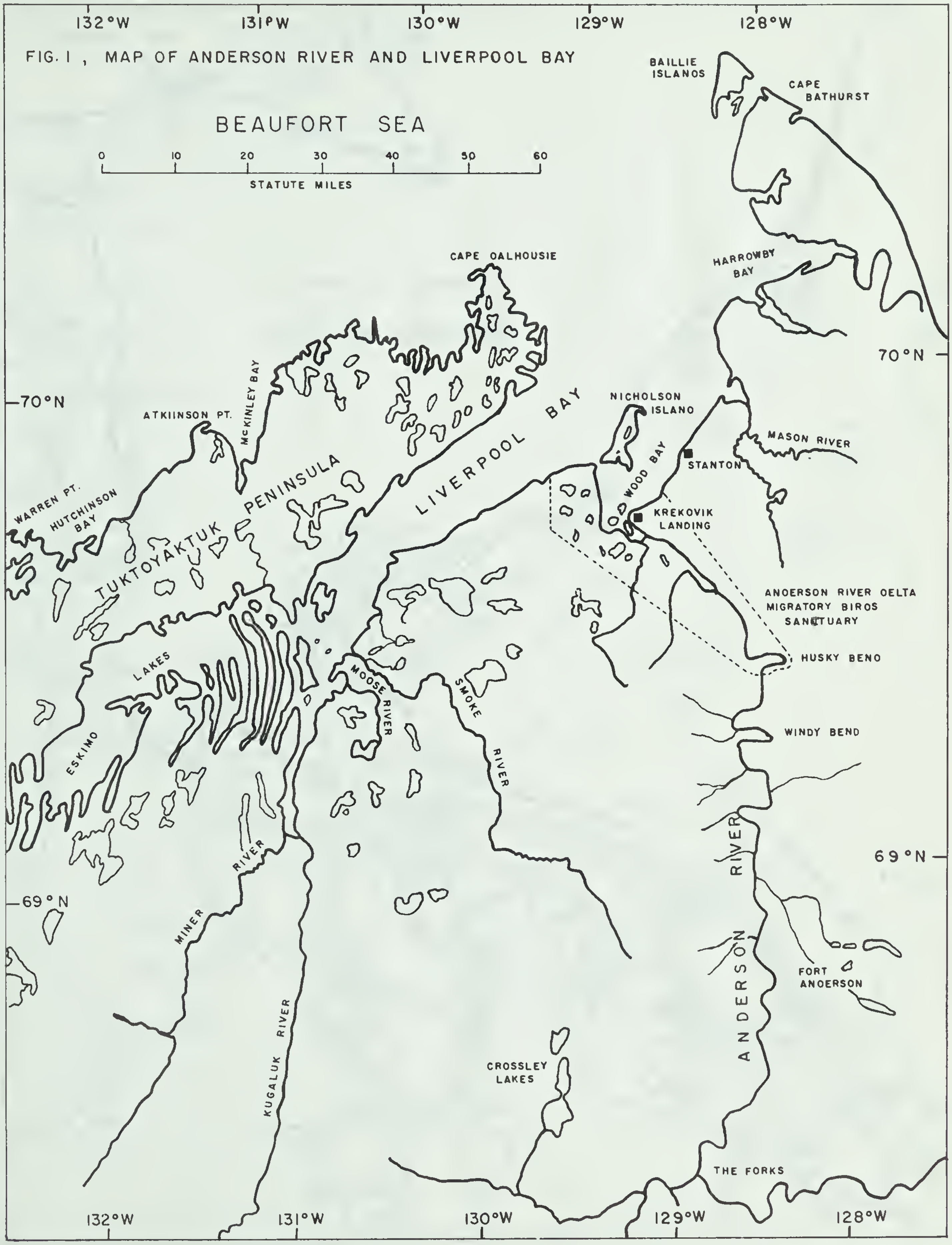


FIG. 1, MAP OF ANDERSON RIVER AND LIVERPOOL BAY

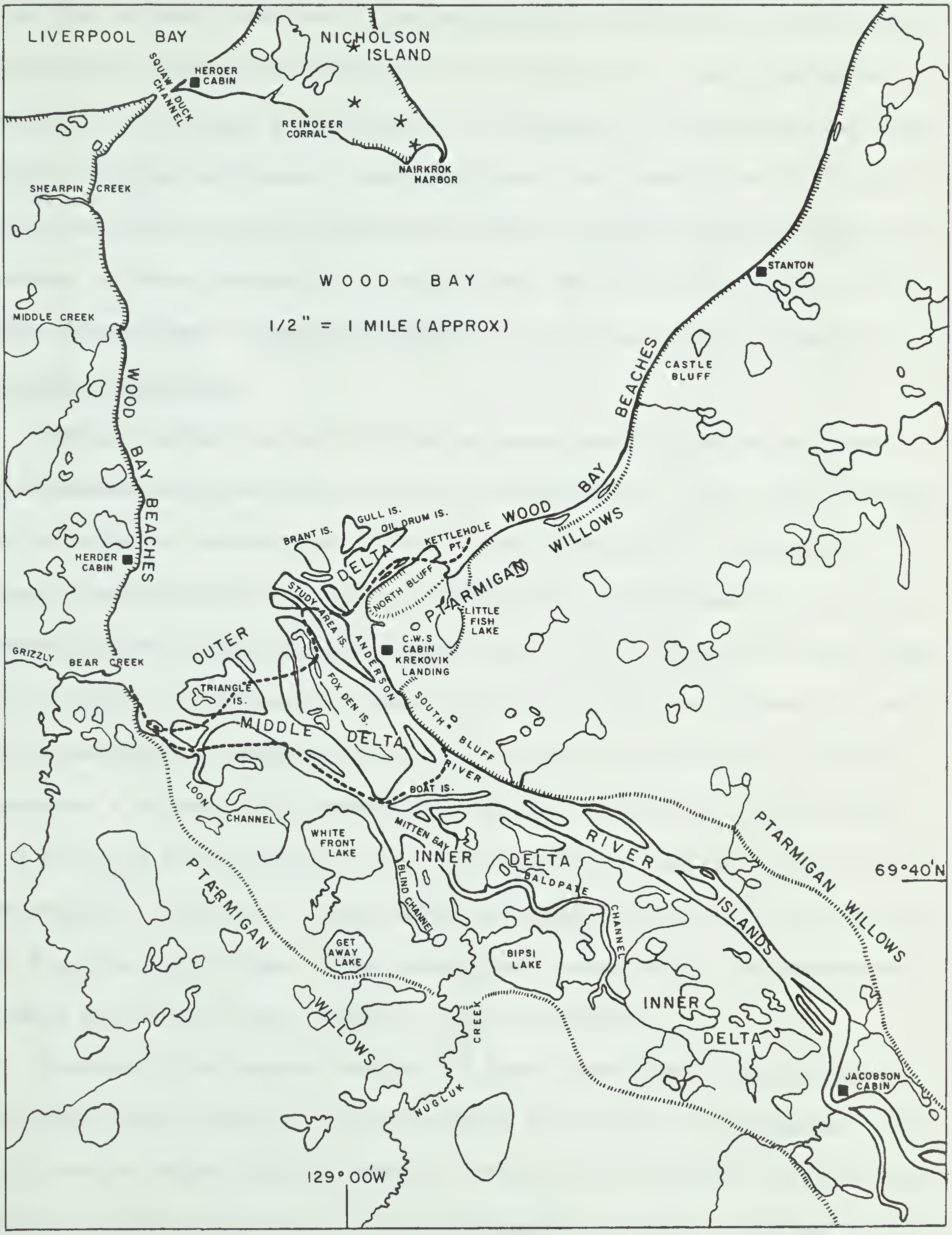


Figure 2. Map of Anderson River Delta.

In the short space of 44 miles, or about $0^{\circ}33'$ latitude, between the tree line at Husky Bend and Nicholson Island, the Anderson River contains many types of arctic and sub-arctic environments in close association. The effect is a rapid progression of latitudinal or deltaic successional stages in flora and fauna. Among the geese, for example, we find high arctic or coastal species like Pacific brant (Branta bernicla nigricans) nesting in close proximity to interior and low arctic geese such as the white-fronted goose (Anser albifrons) or lesser Canada goose (Branta canadensis parvipes).

Marine, lacustrine and fluviatile waters meet in the delta, sometimes separated by as little as several hundred feet. Flat silt islands may be adjacent to weathered shale bluffs, rock cliffs, coniferous forest, marshy prairie or scrub willow tundra. Furthermore on a clear summer day, the temperature may range from $35^{\circ}F$ at Nicholson Island sandspit to $88^{\circ}F$ at Husky Bend. A mere shift of the wind to inshore can cause the temperature to drop more than $50^{\circ}F$ anywhere in the delta. On rare occasions a violent July thunderstorm may be followed in the same week by a blizzard with drifting snow. In one 42-day period Nicholson Island was shrouded in fog for 39 days while the middle delta only 12 miles away was fog-free for 35 days. This exceptional variation in the environment permits the delta's wide variety of flora and fauna.

Because of the unusual variety of geese, waterfowl, shore birds, and other birds attracted to the Anderson River Delta, the Canadian Wildlife Service established the Anderson River Delta Migratory Bird Sanctuary through an Order-in-Council of the Government of Canada in February, 1960. The sanctuary is about 418 square miles in extent, covering the delta and Wood Bay from Husky Bend on the southern boundary to part of Nicholson Island on the north.

Pacific brant, white-fronted geese and snow geese (*Chen caerulescens*) nesting within the Sanctuary are found in the same definite habitat niches they occupy in other goose grounds. How they fit into those habitats, as well as into the arctic environment as a whole, is the subject of this investigation. The study was carried on during all or part of every nesting season from 1958 to 1965. This period of eight seasons allowed comparisons between seasons of high reproduction of young and seasons of average and low reproduction. The attempt to determine what factors in the environment were related to these variations led to studies of weather, food preferences, nest site choices, size of territories, and how the geese contend with other geese and waterfowl as well as with predators, etc. In other words, the community of plants and animals at the Anderson River Delta was studied to see what affects each species of goose and how the goose itself affects its surroundings.

Materials and Methods

In studying geese on their home range one must get the feel of the environment, that is, become attuned to climate, vegetation, water, soil and animals affecting the birds. In time one learns where the mud bars are, when the tide is high, where the geese will go, what the wind and clouds foretell, what the tide rips mean. In short, one is part of the country and always knows which way is North.

But the more the environment is studied in time and space, the more it -- and the beholder -- changes. Much of the "method" of this study was merely being present, season after season, observing. I learned something about the Anderson River, but my own impact on the environment unfortunately interfered, in such subtle ways as scaring a goose from a nest while a bolder predator was nearby or by bringing intrusions by aircraft and motorboats. Such interferences will always be factors affecting any ecological study.

Observations ranged from the purely fortuitous, often made from the cabin or tent, to such deliberately planned programs as beating the bush to locate nests, checks on food habits, or use of a blind to watch individual birds. Location of the Canadian Wildlife Service house on the 25-foot east bank of the delta, overlooking the brant and snow goose nesting grounds, made long-range observations of snow cover, flock movements, etc. easy. My estimates of the per cent of snow cover on the nesting grounds (Study Area Island) were made at regular intervals from the roof of the house. Comparative photographs of the snow cover (Figures 61 and 62) were also taken from the roof.

Place names used on the maps and in the text are those in common usage by residents of the vicinity and are not necessarily those found on published maps. Submissions for recognition as official place names have been made to the Canadian Permanent Committee on Geographical Names.

From 1958 to 1966 I travelled an estimated 25,000 miles over the coastal plains and the Arctic Ocean from Herschel Island to Baillie Islands and Banks Island, concentrating on the Anderson River Delta, the Kugaluk and Smoke rivers, and the outer islands and flats of the Mackenzie Delta. Beaver or Cessna 180 or 185 were the aircraft most frequently used for the many low level (25'-150') survey flights to determine nesting and molting distribution and reproductive success. Boats used ranged from small dories, canoes and scows to a 32-foot motor vessel. A 20-foot square-stern fiberglass covered canoe, powered by a 20 hp motor, was the most versatile for work in the delta and Wood Bay. Snowshoe travel was often necessary in the spring when the snow became soft.

Weather data were kept every day. A maximum-minimum thermometer in a shaded spot 12 inches above the ground recorded conditions of the nesting habitat. Wind direction and velocity (measured with a hand-held anemometer) were recorded at the five-foot level. The wind velocity was greatly reduced on the ground, especially in the snow goose and white-fronted goose areas where vegetation was taller, but no measurements were made near ground level. Precipitation was measured by a standard Department of Transport gauge, either in inches of rain or inches of snow. In Table V and Figure 41 the precipitation converted to inches of rain, ~~and~~ is from the weather records at Nicholson Island Distant Early Warning (DEW) Line Site. Barometric measurements were recorded every evening until the 1964 season when a barren-ground grizzly bear (*Ursus horribilis*)

destroyed the barometer. Cloud cover, so important to the rate of spring thaw, was estimated in tenths of cover several times a day, then averaged. To show the effects of temperature and sunlight on thaw (Figure 59) I added 0° to 5° to the daily mean temperature, depending on the amount of sunshine during the day.

The general yearly routine on the delta was to arrive in early May before any migrating birds, and set up camp for the field season (Figure 3). During the thaw and break-up period travel was severely restricted. Once the wind-hardened crust on the snow softened, snowshoes were necessary except on wind-swept parts of the main channel ice. Once runoff channels appeared it was possible to travel considerable distances using a small square-stern canoe with 5 hp motor. The canoe is equipped with oak runners so it can easily be pulled across the ice from one run-off channel to another.

Daily nest checks were made on the study area, the north half of Study Area Island (Figure 2), beginning about May 20, depending on how early or late the seasons were, and before any geese were observed nesting.

At each nest site, the position of snow or melt water and the depth of permafrost were recorded. Numbered sticks were placed within approximately 10 feet of the nests.

In each nest, the eggs were numbered in the sequence of laying and the dates recorded so that the egg-laying rate and egg predation could be determined. To account for the effect of our presence on egg predation, the clutch sizes of most nests in the delta, including previously untraversed areas, were recorded each year near the end of incubation.

By the end of June or early July, banding operations were begun. During the course of the study, 6,119 snow geese, 3,941 Pacific brant,

Figure 3. Early May at base camp, Anderson River Delta.

and 2,264 white-fronted geese were banded. Sub-adult white-fronted geese (non-breeders) were the first geese available for banding. When the young snow geese were about three weeks old they were large enough for banding. Adults were also flightless by that time, and white-front adults and young were ready. Adult and young brant were ready about 10 days later than snow geese.

Geese were aged and sexed by cloacal examination or plumage characteristics. Brant up to the first annual molt were aged by the white edging on the secondaries. First year snow geese are grayish, while some second year snows retained a gray streak on the back of the head and down the back of the neck. Yearling white-fronts have clear bellies; after the first year the amount of speckling is variable.

Banding of geese continued until all regained flight. By this time, most of the birds were widely dispersed in molt migration, and those remaining soon left for their pre-migration staging areas.

Sub-adult white-fronted geese were the most difficult to capture. During the first week of the molt they sometimes can be surprised and herded into previously set up pens. We have caught as many as 455 in a single drive by this method (Figure 4). After about a week they react differently: large flocks break up into smaller groups and when herded they break up into smaller and smaller groups until individual birds dive, scatter back past the boat, or escape in other ways. We've had the frustration of watching a flock of 1,500 white-fronts disappear before our eyes; we caught only three. At such times, we relied heavily on a Chesapeake Bay retriever (Figure 30) big enough to crash through the tough willows and catch white-fronts we had driven ashore.

Snow geese were easier to capture because of their habit of herding into tight flocks when approached. Because there were so many water holes, sloughs, etc., which made overland herding difficult, we usually drove them into the pen by boat (Figure 5).

Brant were herded in a similar way, but because of their preference for the outer delta and its vast mud flats, brant drives had to be carefully timed with the tide in order to have enough water to maneuver the boats. The behavior of brant while being herded is between that of snow geese and white-fronted geese. If brant are herded too far (more than 3/4 mile), they start breaking up into smaller groups. Once the flocks break up it is almost impossible to drive them back together again, even with a flotilla of boats.

One banding site, at Kettlehole Point (Figure 6), was particularly good because of the deep water off its northern edge, and because it was a preferred feeding place for adult and young snow geese and brant.

The banding pens were usually 50 feet in diameter with leads up to 200 feet long. The opening to the holding pen was about 10 or 15 feet wide. A large pen could be set up in 45 minutes, while smaller pens, mostly used for "hit and run" brant drives, could be set up in about 20 minutes. Hollow aluminum poles were pushed into the ground about every 10 feet along the leads, and every five feet in the circular pen. Nylon nets, 1-1/2 inch stretched mesh of #3 weight, backed on one or both sides, six feet wide, and 150 to 200 feet long, were used. They were overlapped at the back of the pen and laced with side line. The netting was stretched and held to the poles by a series of clove hitches. If it was windy, driftwood logs, sods or heavy wire staples secured the net bottom. If the soil was muddy or wet, the base of the net was simply trampled down and left to be kept in place by the geese standing on it.

If predators were particularly abundant, the leads were drawn together into a makeshift holding pen so banded birds could be held for simultaneous release. This was an especially effective way to cut down glaucous gull (Larus hyperboreus) predation on the brant.

Reports of band recoveries, in the form of IBM cards or print-outs were received through the facilities of the U.S. Bureau of Sport Fisheries and Wildlife Migratory Bird Laboratory in Laurel, Maryland. Neckbands of the type described by Craighead and Stockstad (1956) were also used on some birds of each species, and were most successful on brant, lasting up to 10 years (Figure 7). Brant marked in this study, and others marked at the Yukon-Kuskokwim Delta with different colored neckbands, were used to

Figure 4. Sub-adult white-fronts in pen.

Figure 5. Herded snow geese with young.

Figure 6. Brant at Kettlehole Point banding site.
(Billy Jacobson preparing catch pen.)

Figure 7. Neckbanded female brant.

indicate the arrival dates of birds from these nesting areas at the Izembek Bay, Alaska, staging area. The number observed were used by the U.S. Bureau of Sport Fisheries and Wildlife to estimate the total brant population by a Lincoln index. Experiments by Canadian and U.S. personnel along these lines are still underway.

I rather arbitrarily divided the Anderson River Delta into 10 floristic and geographical areas, some of which are used by geese while others are not. These areas are described in the text, and lists of the plant species and some of the fauna collected from each area are shown in Appendices A through C.

During the earlier years of the study, specimens of white-fronted geese, snow geese and Pacific brant were collected when possible from their wintering grounds, at spring migration stops, throughout the nesting season and at the start of fall migration (Figure 8). Attempts to capture live, newly arrived spring geese for experiments on the effects of controlled habitat conditions met with complete failure, not only because of the difficulty of setting cannon-nets in permafrost, but also because of spring overflow conditions. A large mist net on local goose "flyways" was avoided by the geese, although it was overly successful in capturing shore birds.

Weights in grams or tenths of pounds, as well as measurements, were recorded for all specimens of geese collected. The contents of the proventriculus and gizzard were saved for food habit studies.

The testes, ovary, thyroid and adrenals were fixed in formalin or "AFA". Later, in the laboratory, the testes were weighed, then a portion of each was embeded in paraffin, sectioned and stained with haematoxylin and eosin for studies of germinal development. The amount of lipids in

the testes was measured in another portion by using a lipid stain, Sudan red or Sudan black, against a haematoxylin stain on frozen sections.

Figure 8. Dissection of spring snow goose.

The ovaries were weighed and the numbers of ruptured and atretic follicles determined. Both kinds of follicles are recognizable at least until August (Barry, 1962).

The thyroid and adrenals were also weighed, and the former sectioned and stained with haematoxylin and eosin to measure the height of the follicle cells.

Activity of incubating female geese was recorded on an Esterline-Angus 20-point recorder (Figure 9). Micro-switches approximating the size of a goose egg were fastened to iron pegs set firmly into the nests. The switch connections were in the "normal off" position to reduce the drain on the battery while the birds were on their nests. The switches were connected to the recorder using #16 and #18 double strand bell wire.

Figure 9. Esterline-Angus 20-point recorder.

Figure 10. Brant nest with micro-switch and thermister probe.

A 12-volt car battery served as a source of power. The batteries were recharged at camp with a Bendix portable generator and a fast charger, and replaced every three or four days. Three batteries hooked up in parallel would last seven or eight days.

The presence of the micro-switch did not seem to affect the behavior of the female. It was possible to tell from the record the times she left the nest, the times she shifted eggs, the number of comfort movements, the time of egg predation, if any, and the degree of movement when the young were hatching.

Simultaneously, a thermograph, capable of recording 11 different temperatures (10 incubation and one ambient) was hooked up through long thermister probes to some of the nests. Small mammal rectal probes taped to an egg in each nest proved most satisfactory (Figure 10). A standard air temperature probe was for the ambient temperature. The thermograph was a modified version of that described by Adhav (1963), and was built by the technical services of the University of Alberta.

Food habit studies were carried out by direct observation of feeding flocks and by identification of the contents of the gizzard and proventriculus of the specimens collected. The size of the grit in the gizzard was determined, then the food species were sorted and measured by volume.

History and Prior Study in the Anderson River Delta

The existence of the Anderson River was probably known to Dr. John Richardson of the eastern detachment of the Second Franklin Expedition, who landed on Nicholson Peninsula July 16, 1826. Richardson again crossed Liverpool and Wood Bays in 1848 while heading east to participate in the Franklin Search.

Roderick MacFarlane of the Hudson's Bay Company explored The Forks of the Anderson and downstream at least as far as Husky Bend in June, 1857. Hostile Eskimos prevented his reaching the delta until 1859 (MacFarlane, 1890-91). Working overland from Fort Good Hope he established Fort Anderson on the east bank 35 miles downstream from The Forks on the approximate boundary of what were Indian and Eskimo territories (Figure 11).

Although the fort was in existence for only about four years it is significant because here MacFarlane collected more than 5,000 bird and egg specimens for the Smithsonian Institution and first became aware of the geese at the mouth of the river. The Anderson, which MacFarlane named for the chief factor of the Hudson's Bay Company then in charge of the Mackenzie District, was called the Beghula by Hare Indians who occupied the upper reaches, and the Kraksitormeork by Eskimos of the lower valley (Petitot, 1875). Middens of the latter, now exposed by erosion, contain mostly caribou and goose bones.

Fort Anderson was abandoned in 1865, either because epidemics killed off the native hunters and trappers or because of the difficulty of resupplying the fort with trade goods from Fort Good Hope.

Figure 11. Remains of Fort Anderson 100 years after abandonment. Photo by R. Fyfe.

From 1890's to 1910 whaling frenzy hit the country, and Eskimos became trappers and caribou hunters for the over-wintering whaling ships. Bodfish (1936) gives an account of the amount of meat brought into the ships wintering at Baillie Islands:

"My log shows that during this past winter and the winter before we had received over 47,000 pounds of this meat [caribou]" p. 170). "...we got 344 eggs and six ducks...hunters returned with six muskox [Ovibos moschatus] skins, seven heads and two live calves harnessed to loaded sled. They had cached fifteen other skins and another calf had died en route" (p. 185). "...While we wintered in the arctic they killed all the muskoxen in an area of 150 miles" (p. 186). "...On our way back to the ship we took a circuitous route and came to the camp of some of our

native hunters...they had gathered 50 dozen eggs and piled them in a heap...while they slept six arctic foxes [Alopex lagopus] had carried off and buried all the eggs" (p. 188).

Eager to trade and hunt for the whalers and to use more modern weapons, the Eskimos quickly shot off their food supply of barren-ground caribou (Rangifer arcticus), etc. Also with the whalers came further epidemics, and by the early 1900's the Eskimo population was in a sick, starving, miserable state.

When the demand for baleen whalebone fell in 1910, some of the whalers turned to trapping and trading, and arctic fox along the coast became the dominant item in the economy. People from the river tended to stay on the coast all year round. During the 1920's when arctic fox brought as much as $200 per skin, and other skins also were high, there were trading posts at Kugaluk River, 60 miles east of Anderson River; at Anderson River Delta on Wood Bay, and at Baillie Islands, 75 miles northeast of Anderson River. There were several other smaller short-term traders at intermediate points. All are now abandoned. During the 1930's five to 10 families lived in the lower Anderson. They were mostly white trappers married to Indian or Eskimo women. After 1938, trapping licenses could be held only by natives and those whites and their children who held trapping or "general hunting" licenses before that date. The era of the white trapper in the country slowly died out.

In 1937 a Roman Catholic mission and trading store was established at Stanton, 10 miles up the east side of Wood Bay from the mouth of the Anderson River. The site of the mission building, barely above the storm-tide line, was poorly chosen. There was no harbour and its best reason for existence was good fishing and as a base for hunting, trapping

and wood-gathering up the river or along the coast. About five Eskimo families lived at Stanton until 1955 when, because of the chances of high wages on DEW line construction and poor fur prices, they moved to Tuktoyaktuk. The missionary closed his store and parish, and Stanton has since been abandoned. From 1955 on, there have been no permanent residents and very few transients in the entire Anderson River valley.

In 1938 two herds of reindeer, numbering 2,500 in 1942 (Clarke, 1942), were introduced to the Wood Bay area at the mouth of the river. The narrow isthmus to Nicholson Peninsula made it ideal to control the herd. A driftwood corral still exists on Nicholson Peninsula. A house for the supervisor of the herders was built on the east side of the Anderson River Delta at Krekovik Landing just outside the reindeer grazing preserve. This house, overlooking the goose nesting flats of the delta has been the base of my goose studies (Figures 12 and 13). Unfortunately, the supervisor Stanley Mason and 11 members of the two herder families were drowned in the wreck of their schooner off Cape Dalhousie in 1946. The house was completed in 1947 and for a short period in 1948 it was occupied while the reindeer were driven back to the Tuktoyaktuk area, 100 miles west.

In 1955, Höhn (1959) stayed at the mouth of the Anderson River studying the birds of the area, and in the same year Mackay (1958) travelled by canoe up the Anderson as far as the first waterfall upstream from The Forks. Since then the delta of the Anderson has been completely abandoned except for the waterfowl survey flights of R.H. Smith of the U.S. Fish and Wildlife Service (1949-1966) and the occasional winter visits of trappers from Tuktoyaktuk.

Figure 12. Canadian Wildlife Service house, Krekovik Landing.

Figure 13. Midnight photo of rare thunderstorm.

In 1955 construction began on the DEW-line Site on the north end of Nicholson Peninsula, approximately 16 miles north of the mouth of the Anderson River. From that time to the present it has been occupied by 10 to 24 people who have had little effect on the surrounding area. It is served by an airstrip on the northeast sandspit and its personnel do very little travelling, except to haul gravel on a winter road across the ice of Wood Bay from a beach about 1-1/2 miles north of Stanton. DEW-line personnel are not allowed to use firearms but Eskimos working at the site are. They have shot some geese during the spring migration towards Banks Island, and have shot three or four barren-ground grizzly bears attracted to the site's garbage dump.

Periodically, beginning in 1958, oil exploration geologists, seismic and gravity-meter personnel have travelled the Anderson River country on preliminary surveys.

Thus, in 100 years an area once capable of supporting nearly 600 persons (Mackay, 1958), largely off its game resources, has become depopulated through overuse of the resources, epidemics and a changing economy. Today, the Anderson River bird and mammal populations have nearly recovered their former abundance.

General Geography of the Delta and Related Goose Grounds

The Anderson River country and its delta are part of the low rolling Arctic Coastal Plains. The coastline along the Beaufort Sea and around Liverpool Bay, a pre-glacial outlet of the Mackenzie River and marred and contorted by glacial thrust at Eskimo Lakes, is very complex because the land is slowly sinking. Many lakes are becoming bays and inlets which make good molting and feeding areas for geese. Pingos, the low conical hills formed with an ice core, are the prominent features of the coast. Further south from the sea coast the lakes thin out and meanders of wide-valley rivers such as the Horton, Anderson, Smoke, Moose, Kugaluk and Miner become prominent. It is also along most of these rivers that white-fronts and sometimes Canada geese are common.

In the Anderson valley, particularly within the tree line, tributary streams have cut deeply into the hills, and although nearly dry in summer, contribute much silt to the river itself. Above the present-day flood-plain of the Anderson are erosional terraces, often capped with gravelly soil which gives them a characteristic flora.

From the delta up to Windy Bend the banks and channels are of mud and sand. Further upstream, banks and bottom become more gravelly and stoney. Much of the course of the lower Anderson traverses weathered cretaceous shales which at times of break-up or heavy rains contribute to the turbidity of the river and produce some of the stickiest mud imaginable at the deposition zone of the outer delta.

Because of the sloping sides of the valley, solifluction over the slickened surface of the permafrost is frequent. In some seasons, such

Figure 14. Mud flow caused by heavy rain.

Figure 15. Mud flow at South Bluffs.

as 1963 when heavy rains saturated the thawed layer above the permafrost, mud flows up to a mile long create wide black scars on the hillsides and increase the turbidity of the river to the extreme (Figures 14 and 15).

Flood-plains and levees are built when the river reaches its highest level during spring thaw and break-up. Upstream, variations in water level range from 10 to 25 feet, depending on the width and turns of the channel. Also during break-up, ice jams override the banks, pushing heaps of soil up to the tops of the alluvial banks (Figure 16). These mounds are often bare of vegetation, and later in the summer, when dry and cracked, make excellent hiding places for molting white-fronts.

Height of the flood-plain from The Forks to the delta varies according to the current and depth of the main river channel. At Windy Bend it is about 20 feet above summer water level; at Husky Bend where the river cuts against red and yellow ochre crags, pinnacles and slopes, the plain is at 15 feet (Figure 19). The sulphurous outcrop at Husky Bend was still burning in 1955 (Mackay, 1958) in a fashion similar to that at the Smoking Hills, 75 miles northeast.

From Husky Bend north, the flood-plain widens out into what I consider the head of the delta. There the river channel trends to the east side, and in the 33 miles to Wood Bay the flood-plain declines from 12 feet to sea level. On the flood-plains, especially far back from present channels and around old lake beds, extensive polygons of frost-heaved soil have formed. Their margins are usually depressed by fissures where sedges and grasses outline the polygons (Figure 17).

The Anderson is building its delta out into Wood Bay where now the mud bars and two-foot deep shallows extend about five miles. Discharge into Wood Bay is through two primary channels, each with two secondary

Figure 16. Mounds of soil pushed up by break-up ice.

Figure 17. Soil polygons.

branches. The main channel and the one used for larger boats sweep northeast past Kettlehole Point and across the bay towards Stanton.

But this may all change, because of the break-through of Nicholson Isthmus in August, 1964. Nicholson Island, formerly joined to the mainland by an isthmus 200 yards wide and 15 feet high, is about eight miles long and four miles wide. From the eastern side it rises from 10 feet to a series of 200 to 300 foot ridges lying parallel to the west coast. Features of the southern portion are the many marshy depressions and lakes, and five pingos. Ice lenses and associated soil slumping occur along the eastern coast (Clarke, 1942; Mackay, 1958). At the break in the former isthmus, the tide level differential of nearly 1-1/2 feet had scoured out a channel from 8 to 20 feet deep by 1966 which we have named Squaw Duck Channel (Figure 18). This may alter the course of the delta outlet channels more to the west.

Depending on tides and winds, the fresh water of Anderson River can be detected as far as the northeast sandspit of Nicholson Island. The current past Anderson River house at the mouth of the river is two miles per hour. Salt water on a storm tide can push well up the delta; the effects of storm tides are visible as far upstream as Husky Bend.

Around the Beaufort Sea, and in fact in the entire Polar Basin, the nesting habitats of the geese that are the subject of this study are discontinuous. Common to all goose nesting habitats is the presence of the relatively richer glacial till, unglaciated areas, or bottoms recently emerged from the sea. Which goose habitat is available depends on how these areas are broken into deltas, islets, lakes, etc., and which plants they contain.

Figure 18. Squaw Duck Channel in 1964.

Figure 19. Rock cliffs of Husky Bend near the tree line.

There seems to be two series of goose habitat zones, a latitudinal distribution of the goose species, and an upstream distribution. In the Anderson delta, the latitudinal progressions from the subarctic taiga to a virtual high arctic community is markedly compressed. Superimposed on these latitudinal changes is the development of the river delta, from its outermost mud bars, through its flood-plain, and on upstream where it cuts into rock cliffs, as at Husky Bend (Figure 19). For the Anderson, this is coincidentally also a north-south progression, and it is the most radical of all north-south changes in the delta.

The latitudinal, or upstream, progressions also differentiate the habitat niches of the various geese. Brant nest in the most barren and recently developed habitat, and are found nesting as far north as land goes, in northern Ellesmere Island. They are also found as far out in river deltas and as close to the ocean as possible, to the north on the Anderson and rivers flowing into Queen Maud Gulf, but southwest on the Kuskokwim and south on the Boas River, Southampton Island.

Lesser snow geese are found further south or more upstream as the case may be. They nest on the "lower" arctic islands like Wrangel, Banks, Victoria, King William, Southampton and Baffin, or on suitable mainland sites of Queen Maud Gulf, at Eskimo Point or at Cape Henrietta Maria. Always they are found further inland, by up to 30 miles, than are the brant nesting in the same localities. In the Yukon-Kuskokwim Delta, the band of habitat I would expect to be used by snow geese is occupied by the cackling goose (*Branta canadensis minima*), sub-species of Canada goose. In the high Arctic, where the snow goose does occur, it is the greater snow goose (*Chen caerulescens atlanticus*). Again, it occurs more inland than brant.

White-fronted geese are the most southerly and upstream of the three geese under consideration. They are found on the southern quarter of Victoria and King William Islands, and on the mainland, in upstream locations.

The zoning of habitat niches in a good goose country seems to be controlled primarily by vegetative and geographical features and by predation. In different areas there may be a somewhat different occupancy of certain stages in plant succession, but the factors are remarkably similar. For example, the upstream zonation of species in the Yukon-Kuskokwim Delta is brant, cackling goose, emperor goose (Anser canagicus), and white-fronted goose. At Anderson River the zonation is brant, snow goose, white-fronted goose and lesser Canada goose. On any river flowing into Queen Maud Gulf the order upstream is brant (Atlantic and Pacific), snow and blue goose, lesser Canada goose, white-fronted goose and Ross' goose (Chen rossi) (Barry, 1961 and 1964).

Permafrost underlies most of the goose habitats mentioned above and can have an important effect on the nest and nesting behavior of geese.

Flora and Fauna of the Anderson River Delta

(See also Appendices A through C)

I have divided the Anderson River Delta into 10 geographical-floristic zones upon which there seem to be definite plant and animal associations (Figure 2). In general these zones coincide with latitudinal or upstream stages in plant succession. Not all are used by geese but they fill out the ecological scheme of the Anderson River Delta, affecting the geese in one way or another by providing a source of predators or buffer species or being a factor in snow cover, etc. Similar zones have been described for the Colville River, Alaska, by Kessel and Cade (1958).

1. Wood Bay Beaches: Eastward from Kettlehole Point along the south shore of Nicholson Island and south to the entrance of Grizzly Bear Creek on the west side of the delta, Wood Bay is edged with pure sandy beaches with intermittent stretches of gravel (Figure 20). Most of the driftwood that comes down-river in the spring break-up is washed up on the southeast side by northwest storm tides, hence the name of the bay. In places where sand deposits have built up across identations in the shore line small ponds form with water varying from fresh to brackish, depending on the time of year or whether storm tides have filled them. Above the beaches banks rise from 10 to 100 feet. Silty soil from weathered shales on the east side of the bay is continually falling to the beach and is washed away by wave action. On the west side the soil is a brown loamy glacial till, carrying many erratic boulders. Where the

Figure 20. Wood Bay beaches, Southeast Sandspit, Nicholson Island.

Figure 21. Ice lens exposed by thawing, slumping and solifluction.

wave and tide action reach the cliffs or cutbanks, there is little chance for vegetation to grow. Where solifluction has caused slumping and land slides north of Stanton, ice lenses four to five feet thick just under the organic layer have been exposed (Figure 21). Similarly, wave action on Nicholson Island near the old reindeer corral has exposed an extensive sheet of ice.

Characteristic plants of the Wood Bay beaches are Gramineae: *Elymus arenarius* var. *mollis*; Caryophyllacea: *Arenaria peploides* var. *diffusa*; Boraginaceae: *Mertensia maritima*; Compositae: *Artemesia tilesii*. The beaches along the southeast shore of Wood Bay are usually swept clear of snow by wind most of the winter, and are the first to clear in spring. Projecting drift logs are perches for snowy owls (*Nyctea scandiaca*) and gyrfalcons (*Falco rusticolus*). During the early spring the beaches attract the first of the arriving flocks of snow geese, whistling swans (*Olor columbianus*), white-fronts and brant. Here they gather grit and feed to some extent on the exposed vegetation, especially along pond edges behind the beaches.

Although the geese seem to use the beaches largely for grit-gathering they are also a main avenue for molt migrations by brant and snow geese leaving their nesting areas. When molting flocks are disturbed they quickly head for the nearby water. The birds seldom linger on the beaches but keep moving to such places as Mason River, 20 miles to the northeast, and to Grizzly Bear, Middle and Shearpin creeks on the west side of the bay, as well as through Squaw Duck Channel to the shores of Liverpool Bay.

Beaches are also used as loafing places for molting old squaws (*Clangula hyemalis*), greater scaup (*Nyroca marila*) and scoters (*Melanitta* spp.). This is especially true of Squaw Duck Channel and the southeast

sandspit of Nicholson Island, and, on the mainland, the beaches north of Stanton to the Mason River sandspits.

Moose (Alces americana) usually immature males, driven north from tree line, presumably by insects find the beaches an easy and nearly always breezy path of transportation. Caribou use the beaches on their southward migration from Bathurst Peninsula during late July and early August. Wolves (Canus lupus), barren-ground grizzly bear, arctic fox, red fox (Vulpes fulva), and occasionally wolverine (Gulo luscus) follow the beaches in search of food. Arctic ground squirrels (Citellus parryi) use the cliffs above the beaches, especially on the south and west facing slopes where the permafrost is deep enough to allow burrows. Bears often dig out huge holes in the banks to get at the ground squirrels. Lemmings (Dicrostonyx groenlandicus) and voles (Microtus oeconomus, etc.) seldom use the beaches except where Elymus arenarius has formed a thin turf in which they can build nests and runs.

In late July and early August the bearded seal (Erignathus barbatus), normally a beast of the flow edge and pack ice, uses the beaches for resting and sunning.

2. Outer Delta: From Kettlehole Point on the east and arching across Wood Bay to the mouth of Grizzly Bear Creek is a series of islands and mud bars forming the outer delta of the Anderson (Figures 22 and 23). This is the newest and lowest part of the delta, frequently inundated by storm tides, and containing the pioneering species of plants in the seral development of delta flora. The soil is silty mud when wet, but can become dry, cracked and wind-blown, especially in early July. Because of annual salt water submergence, the soil is very high in sodium and

and chloride (Table I). It is interesting that Brant Island soil has the highest nitrate content of any sampled in the area, probably because of the intense concentration of brant nesting there and fertilizing the ground.

The pioneering plants of the outer delta are either tolerant to brackish conditions or else require it for existence. Characteristic plants are Gramineae: Elymus arenarius var. mollis, Dupontia fisheri, Puccinellia phryganodes, Arctophila fulva; Cyperaceae: Carex subspathacea; Juncaceae: Juncus balticus var. alaskanus; Salicaceae: Salix arctica; Caryophyllaceae: Stellaria humifusa; Rosaceae: Potentilla edgii.

The outer delta is the primary nesting habitat of the Pacific brant, arctic tern (Sterna paradisea), king eider (Somateria spectabillis) and old squaw. During the nesting season brant become land grazers like other geese, feeding almost entirely on Carex subspathacea, Puccinellia phryganodes and other turf-forming grasses and sedges. They also use these species, as well as Elymus arenarius, arctic willow and fragmented driftwood, for nesting. Glaucous gulls use the higher spots for nests, which they construct mainly of wave-cleaned roots of Carex subspathacea, Elymus arenarius and Dupontia fisheri. Often they take over abandoned or destroyed brant nests or will even steal brant down to incorporate into their own nests. The gulls nest in a colony of about 200 birds on Gull Island, and a few pairs are scattered elsewhere in the outer delta.

Although it is one of the outermost islands, Gull Island rises two to three feet above the surrounding mud flats. Gulls usually share the island with about 15 pairs of snow geese and 20 pairs of brant. The gulls of this particular colony do not rob nests of eggs to the extent reported elsewhere, but are important predators on young geese, ducks and swans.

Figure 22. Outer delta showing turf.
(Carex subspathacea and Puccinellia phryganodes.)

Figure 23. Outer delta showing high tide line.

Table I. Soil test results.

(values given as parts per million)

	Nitrate	Phosphorus	Potassium	Calcium	Sulfates	Nitrite	Ammonium	Na	Cl	Soluble Salts	Soil Reaction pH
Outer Delta, Kettlehole Point	9	0.5	30	50	200	0.2	2	v.h.*	300+	10.0	7.1
Outer Delta, Brant Island	90	nil	82	150	300	nil	2	v.h.*		7.0	7.3
Middle Delta, Study Area Island	10	0.5	26	80	200	0.2	3	v.h.*	50	3.4	7.7
Good soil	20-40	5-10	20-30	100-150	50	nil	nil	-	-	1-2	6-7
Tolerance limit, greenhouse plants	125	50	50	200	450	2	50	-	-	3-4	-

*very high

Few mammals ever cross the outer delta, and none live there. I have recorded only wolf, caribou, grizzly bear and arctic fox there, and a bearded seal which once chose a dry piece of turf for basking.

Geographically, the outer delta is the most dynamic. Silt is being deposited more rapidly there than elsewhere, channels change and new mud bars appear each year. Species of plants can pioneer on the new ground without competition, and once established they attract further deposition of soil and animal fertilization (Savile, 1960 and 1961).

3. Middle Delta: The middle delta is composed of the southern parts of the delta islands, that is, the upper part of Study Area Island, Fox Den Island, Triangle Island, etc. (Figure 24). This area, older in formation, is about three or four feet high, and is characterized by low cutbanks as distinguished from the flat mud or marsh edges of the outer delta. Storm tide inundation occurs only about every other season. Old channels and rotted drift logs have broken up the flats into ridges and hummocks so that there are areas high and dry enough for arctic fox dens. Surprisingly, there are often broad stretches of bare mud, interspersed with willow, which might be the result of heavy activity by snow geese, the dominant nester, or may represent an hiatus in the seral development of plants. The land apparently is too high and well-drained, or lacks the seasonal tidewater submergence that permits turf-forming sedges and grasses to grow. The grass Elymus arenarius var. mollis does grow on the flatter, lower portions. Where it approaches continuous cover, it is not used by snow geese for nesting, but where it is interspersed with willow or Calamagrostis neglecta, the geese are quick to use it for nest material or for food in early spring. This may result in overuse, causing the bare

Figure 24. Middle delta, Study Area Island.

patches and perhaps a shift of snow goose nesting concentrations from one island to another.

Dominant plants of the middle delta are Potamogetonaceae: *Potamogeton vaginatus*; Gramineae: *Calamagrostis neglecta*, *Elymus arenarius* var. *mollis*, *Dupontia fisheri*; Cyperaceae: *Eriophorum angustifolium*, *Carex aquatilis*; Salicaceae: *Salix arctica*; Ranunculaceae: *Anemone parviflora*; Hippuridaceae: *Hippuris vulgaris*; Gentianaceae: *Lomatogonium rotatum*.

The snow goose colonies are concentrated on those slightly elevated ridges and hummocks that are the first to clear of snow and are likely to remain dry during spring flooding. In the more grassy areas, Lapland longspurs (*Calcarius lapponicus*) nest abundantly; they have been seen stealing bits of down from snow goose nests for their own purposes.

A small colony of arctic terns shares with old squaws a nesting site in the south end of Study Area Island. The middle delta is also the start of the widely dispersed nesting sites of whistling swans, which prefer the wetter grassy areas.

The middle delta supports a greater variety of mammals than the outer islands. Lemmings are occasionally found here on the higher ground, but this is marginal habitat for them. Microtus occur where stands of Elymus arenarius are thick, but they are never as abundant as on the mainland. Arctic fox successfully reared young in 1958, 1959 and 1960 on a willow-covered hummock on Fox Den Island. The den was occasionally used thereafter, but it slowly filled with permafrost and became plugged with ice. While in use, the site produced some interesting band recoveries from geese as well as much information on food habits of fox. Barren-ground grizzlies, wolves, and wolverines have in some seasons made hunting forays onto the middle delta, but the red fox, common in the higher country of the mainland, has never been seen on the delta islands or the wet lowlands of the inner delta. During the insect season, from the latter part of June through August, caribou and moose are often seen on the breezy middle and inner delta flats as well as along the Wood Bay beaches. Occasionally they wallow in the mud and water of the sloughs, and once a moose spent a long period in the water with just his nose and the top of his head out. He frequently put his head underwater to rid himself of pests. (The Anderson River country has the worst hordes of mosquitos of any place I've experienced in the Arctic.)

4. Inner Delta: Consisting mostly of the flat marshy prairie of the mainland, the inner delta intrudes into the central part of Fox Den

Island. It is flat, studded with many lakes and sloughs, and has lush vegetation in the poorly drained marshes. Cutbank edges on channels and lakes are rare, the banks tending to be rounded and covered with mats of creeping willow and grass. These edges are slightly raised levees, and act as barriers to drainage. Fewer willows grow in the marshy areas except on the ridges where ground birch (Betula glandulosa), crowberry (Empetrum nigrum) and cranberry (Vaccinium vitis-idaea) also occur. Ice pushes on the edges of lakes form grassy ridges.

Much of the vegetation is mixed sphagnum and sedge in lush green meadows, but so sodden that the permafrost is only 8 to 10 inches below the surface in the summer (Figure 25). Some lakes of the sphagnum meadows have ice bottoms at depths of only two feet. Shallower sloughs are mud-bottomed, and by early July become choked with Hippuris vulgaris, an excellent escape cover for ducklings and goslings. Further inland, where the flood-plain is slightly higher, hummocks of grass form high enough to allow a hydrophilic form of willow to grow to heights of about 2-1/2 feet. Widely dispersed are small dark clumps of alder (Alnus crispa) four to five feet high; on the horizon of the broad flats they can be mistaken for moose or bear.

The major plants of the inner delta are more varied and lush than those of the middle and outer delta: Equisetaceae: Equisetum arvense; Potamogetonaceae: Potomageton vaginatus; Gramineae: Dupontia fisheri, Arctagrostis latifolia; Cyperaceae: Eriophorum angustifolium, Carex rariflora, Carex scirpoidea, Carex aquatilis, Carex capillaris var. major; Salicaceae: Salix arctica, Salix alaxensis, Salix pulchra; Corylaceae: Alnus crispa; Polygonaceae: Rumex arcticus; Ranunculaceae: Ranunculus trichophyllus, Ranunculus pedatifidus, Anemone parviflora;

Figure 25. Inner delta, near White-Front Lake.

Cruciferae: Cardamine digitata, Cardamine praetensis var. angustifolia; Rosaceae: Potentilla palustris; Leguminosae: Lupinus arcticus, Hedysarum alpinum var. americanum, Astragalus alpinus; Hippuridaceae: Hippuris vulgaris; Primulaceae: Primula borealis; Scrophulariaceae: Pedicularis arctica, Castilleja pallida ssp. elegans.

The inner delta swarms with insects and aquatic invertebrates, as attractive to a varied bird population as is the vegetation. The many ponds, lakes, channels and sloughs are occupied by many water birds with no one species predominating. Whistling swans are widely dispersed, preferring nest sites near the larger bodies of water. Arctic loons (Gavia arctica) also choose edges of large lakes, while red-throated loons (Gavia stellata) often nest on the edges of ponds barely large enough for them to make a successful take-off run. Most of the smaller ponds and sloughs are occupied by northern phalaropes (Lobipes lobatus) and scaup.

The marshy meadows are the nesting grounds of pintail (Anas acuta), green-winged teal (Anas carolinensis), and occasionally a shoveller (Spatula clypeata); such shore birds as Hudsonian curlew (Numenius phaeopus), pectoral sandpiper (Erolia melanotos), semi-palmated sandpiper (Ereunetes pusillus), and, near the willow margins, the Hudsonian godwit (Limosa haemastica). The white-fronted goose and black-bellied plover (Squatarola squatarola) nest on the drier hummocks and ridges inland. The lush meadows, especially those of Loon Channel, are favored by molting snow geese and their young.

The larger lakes and channels, as well as the main river, are also used by white-fronted geese to raise their young, but as more molting and loafing grounds by the one and two-year-old non-breeding white-fronts associated with nesting pairs.

Some lakes and channels have an occasional muskrat (Ondatra zibethica), and mink (Mustela vison) are sometimes seen. Arctic and red fox are usually absent, but microtus may be abundant, even in some of the wetter areas. Moose seem to prefer the taller alder and willow clumps on the edges of channels and lakes, while caribou find the grazing on the inner delta particularly attractive.

The inner delta is rarely inundated by storm tides or spring floods (each type of flooding was observed only once in nine seasons).

Distribution of potamogeton beds so extensively used by swans, baldpates (Mareca americana), pintails and brant is controlled by the ice freezing to the bottom of the shallower channels and Mitten Bay during the winter. Erosion action of the river ice during break-up is confined to the deeper channels, while anchored ice in the shallows remains intact during the runoff and collects a layer of silt. Thus the potamogeton beds remain undisturbed. The potamogeton also traps considerable amounts of silt carried by the river after break-up, and from rains and mud flows later on.

5. Tributary Streams: There are five important tributary streams in the lower delta region that are navigable by canoe for distances up to 10 miles upstream. The character of each is somewhat different depending on how much of the flood-plain the stream traverses. The current varies with the length and gradient but all are subject to tidal currents in their lower reaches.

Shearpin Creek, draining into Wood Bay near Nicholson Island, amounts to a breakthrough draining a lake about two miles inland. It is entirely tidal and therefore has vegetation similar to that of the

outer delta, changing abruptly at the scrub willow and dryas-covered hills. The flats of Shearpin Creek are excellent brant habitat, and are used extensively by adults and young. But because of their close connection with the surrounding rolling country, which has good fox-denning sites, the creek flats are seldom used for nesting by brant; predation undoubtedly wipes out any attempts at nesting.

Green-winged teal, pintail, white-rumped sandpiper (*Erolia fuscicollis*) and a few glaucous gulls do nest there. The remains of a drained lake bed also are favored by white-fronted geese and sometimes by swans. The geese find deep water next to the hills, lush food on the flats, and their favorite escape cover, scrub willow, close at hand. The low draw between this basin and the next creek system south, Middle Creek, is regularly used by molting white-fronts. Brant, on the other hand, are not at home in the willows and move from one creek to another by way of Wood Bay and its beaches. Snow geese seldom make use of the basin of Shearpin Creek for nesting or molting.

Middle Creek drains into Wood Bay from two tributaries which meet about one mile upstream. The lower reaches are tidal and turf-covered like the outer delta, and because the flats are broken up into more lakes and islands it provides a certain amount of brant nesting habitat. Middle Creek is also highly favored for broods of snow geese, white-fronts and brant.

The northern tributary flows between rolling hills for about a mile and then drains a large grassy meadow about two miles across, somewhat of the same character as the inner delta. The drier willow-covered hummocks and hills near the stream are nesting places of white-fronted geese and golden plovers (*Pluvialis dominica*). Molting snow geese and young often follow the stream up to the meadow.

The south tributary drains a lake and winds through low-banked flats between the hills. Beyond normal tide effects the stream is clear and rather swift. *Carex aquatilis* is the dominant sedge on the edges, while the bottom has *Hippuris vulgaris* and the aquatics *Ranunculus trichophyllus*, *Sparganium hyperboreum* and *Eleocharis acicularis*.

Grizzly Bear Creek is similar to the other two draining into Wood Bay. We named it for the grizzly bear den dug into the sandy loam of the southwest-facing bank just inside the sandspit at the entrance (Figure 26).

The creek is used for nesting by white-fronts and swans. One of the tributaries drains a lake which can be reached by pulling a canoe through the narrow stretches or by riding in on an exceptionally high tide. The southern tributary winds among flats between the hills similar to the southern tributary of Middle Creek. However, there is an inconspicuous branch draining the higher rolling lake country behind. From its outlet in the marshy flats it is quickly crowded in by the hills and winds between steep cutbanks. It is deep and swift, and can be followed for at least 10 miles. There are no appreciable amounts of bottom vegetation, and the cutbanks are edged with tall willows (*Salix alaxensis*) reaching heights of 10 to 12 feet. This stream, and the two others like it further up in the delta, seem to be the main routes of immigration for swan and white-front broods hatched in the uplands and taken to the delta for rearing.

Nugluk Creek drains the hill country to the southwest and meanders across the inner delta; it has cut down through the flood-plain making cutbanks about six to eight feet high. Sandy beaches have been deposited inside meanders, and above them are slight levees built of

Figure 26. Bear den, Grizzly Bear Creek.

Figure 27. Nugluk Creek, tributary stream.
(Moose in Salix alaxensis.)

driftwood and silt and covered with a band of willow (Salix alaxensis) about 12 feet high. These willow stands are favored summer bedding areas for moose, and as many as four have been chased up at one time (Figure 27).

Behind the tall willows about 25 yards from the bank begin the marshy meadows and willows of the inner delta. The banks of Nugluk Creek and the islands of the main river further upstream are the only places where Canada geese have been found nesting.

The creek near Jacobson Cabin still further upriver is very similar to Nugluk Creek except that it drains a higher flood-plain and therefore has higher cutbanks. A branch entering near a lake at about 69° 38' has had an active beaver lodge. This house, constructed of willow and alder against the bank is, I believe, the "furthest north" beaver (Castor canadensis) in the Arctic. As there is little aquatic vegetation in either this creek or Nugluk, they are important to geese mainly as avenues of brood movement.

The main river channel, as well as the various delta channels, are much used by waterfowl. Ducks, geese and swans nest along these banks, especially where levees have formed. Also, along with some of the larger lakes, they are important molting retreats for swans, white-fronted geese, pintails and baldpates.

Edges of the channels are either cutbanks or shallow mud bars where the emergent grass, Arctophila fulva, and a sedge, Carex aquatilis, are dominant, and are heavily grazed by white-fronts. In the shallower parts of the channels or in the clear-water stretches, especially in Baldpate Channel and its branches, aquatic plants become very dense in the warmer seasons. Potamogeton vaginatus is dominant and is a major food of swans,

brant, baldpates, pintails, as well as for the few scaup and canvasbacks (Aythya valisineria) occurring there. In the spring, potamogeton becomes available with the first appearance of melt water, and swans and puddle ducks use the wintered-over strands frozen in the ice. They continue to feed on leaves and roots until fall migration. By early August, when potamogeton strands mat the surface, brant and their young congregate over the beds in the channels between the middle and outer delta.

6. River Islands: The upstream islands of the river are of two distinct types, each with its characteristic vegetation and mode of formation. The high-banked river islands are cut from the surrounding flood-plain by the river, and are the same height and character as the flood-plain itself, except perhaps for ice pushes on the upstream end.

The other type of island is formed by silt and gravel deposition (Figure 28). As they are lower than the river banks, they usually have sloping sides of sand or silt. Probably they once were sand or mud bars that developed in slack water of the river. On the larger islands of this type the centers are usually depressions with a marsh or small slough, while the edges form low levees. Some of the lowest islands are inundated by spring break-up, while others are being secondarily eroded and have low cutbanks from the new course of the river.

The constant silt deposition of the low islands leaves an open ground cover where plants such as Equisetum arvense, Rorippa sinuata var. columbiae, and Matricaria ambigua pioneer. Equisetum, in my opinion one of the most widely used animal foods in the north, is taken by white-fronted geese. The lower river islands are seldom used for nesting except occasionally by arctic terns, common or mew gulls (Larus canus), glaucous gulls and ringed plovers (Charadrius hiaticula).

Figure 28. Low river island.
(Note willows protected by ice-scoured rock.)

7. Ptarmigan Willows: The flat country of the former flood-plain and the lower hills are covered by a dense stand of bush willow and occasional stands of ground birch about 2-1/2 to 3 feet high. This type of country, especially the flat land around the Anderson River house, we've called the ptarmigan willows to indicate the large variety of willow species and the large numbers of willow ptarmigan (Lagopus lagopus) that feed here in pre-nesting flocks in early spring (Figures 29 and 30). Ptarmigan also nest there, in densities as high as 25 pairs per 1/8 square mile in seasons of high populations. In March, April and May, flocks of up to 500 ptarmigan feed among the willows between North and South Bluffs. Only the top two or three inches of the willows are exposed above the hard-packed snow, and nearly all the new buds and twigs of the prior year's growth are sheared off by the birds. Willows trap the snow to a

Figure 29. Ptarmigan willows and caribou.

Figure 30. Ptarmigan willows.
(Sam Barry and Chesapeake retriever)

uniform depth and the few twigs above the snow are cut back by the ptarmigan. Where deep drifts form along the river bank, the willows grow to heights of five to eight feet, in spite of the fact that the deep snow takes longer to thaw and considerably shortens their growing season. In spring, the short willows on top are always in full leaf while taller ones under the banks are still brown.

In the more poorly drained sections of the ptarmigan willows soil polygons have formed, creating many small water holes and swales around their edges. The pushed-up hummocks are usually covered with cranberry, crowberry and bearberry, but newly formed polygons are bare in the centres. Interspersed in the willows is a variety of grasses, sedges, etc. In the early spring, snow geese, swans and white-fronts often root out the sedges and feed on the overwintered berries. In the fall they are used to a lesser extent by snow geese and swans, but of course ptarmigan use them in large quantities.

Other than by ptarmigan, the willows are used for nesting mostly by passerines. Most abundant are white-crowned sparrow (Zonotrichia leucophrys), tree sparrow (Spizella arborea), savannah sparrow (Passerculus sandwichensis), hoary redpoll (Acanthis hornemanni) and common redpoll (Acanthis flammea). Marsh hawks (Circus cyaneus) are seen regularly, and short-eared owls (Asio flammeus) are very abundant in years of abundant microtus. In such years I've observed short-eared owls in migration at a rate of one bird every 1-1/2 minutes for nearly three days. In seasons of vole scarcity short-eared owls are hardly ever seen, even in migration.

The ptarmigan willows are also the principle nesting grounds for Wilson's snipe (Capella gallinago) and semi-palmated sandpiper. Pintails nest in the willows, but for some reason these nests seem to fall prey to jaegers more often than other pintail nests elsewhere.

Red fox, which seem to have increased in numbers since the start of the study, are most frequently observed hunting among the ptarmigan willows. They are much paler in color than southern red foxes. Two black-phase foxes were seen for several seasons. Tundra shrews (Sorex tundrensis), least weasel (Mustela rixosa) and short-tailed weasels (Mustela erminea) are also found in the ptarmigan willows. The last was particularly abundant during the high vole population in 1963.

8. Dry Hilltops and Nicholson Island: The tops of South Bluffs (187 feet) and Nicholson Island (300 feet) are more characteristic of the high arctic in vegetative growth than any place else in the vicinity. They are better drained and more windswept. Willows grow only up to 10 inches and are sparse. Plants like dryas predominate and form little hummocks covering the surface nearly like a mat. Golden plovers and ptarmigan nest in this country. Höhn (1959) reported rock ptarmigan (Lagopus mutus) on Nicholson Island.

9. Cliff Faces: The decomposing shale cliffs, particularly those of South Bluffs, have a distinct community of their own (Figure 31). South Bluffs is one of the few places in the northern part of the delta where fireweed (Epilobium angustifolium) is found. Common plants which hold to the cliffs are Betulaceae: Betula glandulosa; Caryophyllaceae: Stellaria edwardsii; Cruciferae: Erysimum inconspicuum, Descurainia sophioides; Saxifragaceae: Saxifraga reflexa; Onagraceae: Epilobium angustifolium; Polemoniaceae: Artemesia frigida, Petasites frigidus.

Many arctic ground squirrels den in the South Bluffs as well as in other south and west exposures of the river bank. In alternate years

Figure 31. Face of South Bluffs with golden eagles' nest.

of the study golden eagles (Aquila chrysaëtos) have occupied a large 40-foot nest in the South Bluffs, and in the odd years have nested at other sites along the cliffs (Figures 15 and 31). The main nest site was already large in 1955 when Höhn visited it. A mile further upstream is the nest of a peregrine falcon (Falco peregrinus) which has been used every year of the study; it also was seen by Höhn. In 1966 a new cave-in of the bluff rim made what appears to be a more attractive site, and the falcon eyrie was moved 50 feet from the old site. The faces of South Bluffs are usually windswept and are partially clear of snow all winter.

10. Upstream River Banks and Flood-plain: River banks upstream are broadly U-shaped, primarily from ice action. Often there are cutbanks just below the flood-plain level. The sloping shores are sandy or silty

up to Windy Bend, and boulder-paved above Windy Bend. The vegetation of the banks is that which can withstand ice and high water: willows, sedges, onion, etc. (Figures 32 and 33).

If one looks hard enough, spruce trees are found all the way to the mouth of the river, at 69° 42' N. In the ptarmigan willows, they grow no higher than the two or three foot willows, have long runner-like branches extending from a main stump, and could more rightly be called bushes. On the southwest facing hills about 20 miles upstream a few scattered trees about five or six feet high stand above the surrounding vegetation. At 30 miles upstream, just before the valley swings into Husky Bend, is a stand of spruce I consider the tree line. As one proceeds upstream other species such as aspen, birch and tamarack make their appearance, as described by Mackay (1958).

The predominant waterfowl in the spruce forest or upper part of the river, not a part of this study, are Canada geese, nesting mostly on the river islands, and white-winged scoter (Melanitta deglandi), scaup, bald-pate, etc., which frequent the sloughs, old oxbows and lakes of the flood-plain. The tree line sharply limits Harris' sparrow (Zonotrichia querula) and Bonapart gulls (Larus philadelphia). In spite of our close proximity to tree line, I have never seen these species north of Husky Bend, but the hawk owl (Surnia ulula), pigeon hawk (Falco columbaris) and mew or common gull, all common south of the tree line, are occasionally seen around the house.

Figure 32. Upstream river valley showing flood-plain and islands.
Photo by R. Fyfe.

Figure 33. Upstream river bank.
(Earl Merrander's abandoned trapping camp.)

Weather and Phenology of Seasons

The northern part of the Anderson River valley lies in the Arctic, the southern part in the Subarctic. My criteria for the division is the line of somewhat clustered spruce trees just below Husky Bend. The protection of the Anderson River valley allows the tree line to project a considerable distance north relative to the surrounding country.

The annual range of mean monthly temperatures of the delta is about 70°F, from a low of -20 F in January-February to a high of 50°F in July. Minimum winter temperatures may drop to -60°F, with maximum summer temperatures of 85°F. The mean annual precipitation is about 10 inches with roughly half the total in the form of snow (Mackay, 1958).

Continuous daylight begins at the North Pole on March 21 and progresses south until on June 21, for one day only there is continuous daylight on the Arctic Circle. Continuous daylight then retreats north and ends at the North Pole on September 21, six months after it started in the spring. The further north of the Arctic Circle one is, the longer the period of continuous daylight; at the Anderson River Delta, 69°42'N, continuous daylight begins May 15 and ends July 28, a period of about 47 days. It never gets really dark at night from about May 3 until August 14.

At the delta where the river channels spread out, break-up of ice is about a week later than it is at The Forks (Preble, 1908). It usually takes about eight hours for the front of the break-up to pass from South Bluffs to Anderson River house 1-1/2 miles downstream. Break-up is always a day of celebration at bush camps, and Krekovik Landing is

no exception. Break-up dates at the mouth of the Anderson are shown in Table II.

In the Anderson Delta break-up is preceded by a rising of the floating ice over deep-water channels. Ice at the edges and shallows remains frozen to the bottom, forming troughs for runoff surface water and slush. As the flow increases from upstream, water begins welling into the troughs along parallel cracks on either side of the floating center ice. The center ice has varied in thickness from 6'1" to 8'4" during the course of the study, depending probably on the amount of snow on top of the ice. Overflow in the troughs quickly becomes muddy, and a strong current develops. Before the ice finally goes out, these runoff channels become six to eight feet deep and can be travelled in small canoes with motors to almost any spot in the delta. The main body of the ice becomes candled to a depth of 1 to 1-1/2 feet, but remains firm until only a few hours before break-up. About three days before break-up the bottom ice which has been frozen to the shores and shallows rises to the surface, usually in solid, blue, mud-covered chunks, rectangular in shape and about 25 feet by 75 to 100 feet long (Figure 34).

The floating bottom ice soon forms jams in the runoff channels, and because it is not candled the rafts remain firm until the water rises locally behind them, and they push ashore or twist and break free.

Because of the delta's wide expanse, there is usually very little flooding of the delta islands at break-up. Once the ice and driftwood front passes the house, 1/2 mile from the mouth of the river, the water drops about two feet in 24 hours, and, except for tidal changes of one or two feet, this remains the river level for the next couple of weeks. 1964 was the only year in which there was extensive flooding, and this was on a line from South Bluffs to Grizzly Bear Creek.

Figure 34. Runoff channel with floating ice.
(Bottom ice, just emerged, blocks channel.)

Break-up itself is a rather unspectacular but fascinating phenomenon to watch. Even though the line of driftwood which marks open water may be within sight at South Bluffs, the ice in front of the house 1-1/2 miles downstream remains firm enough for crossings. Within a few hours dark patches of water appear in the ice which has been dissolved from beneath by the warm river current. As these current holes enlarge, the pressure of rising water squeezes sections of rotten ice together to fill the gaps. The water continues to rise, and slabs of ice, now only three feet thick, break loose and some are pushed ashore. In this way the front driftwood and ice debris slowly passes, and open water is once more on the river (Figures 35 and 36).

Following the ice and feeding among the driftwood are baldpates, white-fronted geese, pintails, green-winged teal and common gulls which

Figure 35. Start of break-up.
(Rotten ice dissolves, pushing into open patches.)

Figure 36. Heavily candled ice pushed ashore with driftwood.

normally nest further upstream. During three break-ups beaver followed the ice out to salt water.

Considering the thickness and amount of ice on the river the day before, probably only about 25 per cent is actually involved in the break-up process. The rest apparently warms up and dissolves as the great volume of warm water from the south runs out to sea in Wood Bay.

Timing of break-up appears to be more complicated than the clearing of snow from the land. Ice thickness is a factor, and this is dependent upon temperatures from late September or early October freeze-up until May, as well as upon snowfall and to what degree the ice is swept free of snow by wind. In some years winds keep the ice clear in stretches north of tree line.

The progress of spring thaw, snow clearance and runoff is dependent upon weather patterns during May and June, the amount of open leads in the Beaufort Sea, and the wind direction. In 1959, runoff channels started May 15 under bright sunny weather, but a northeasterly wind pattern from the polynia off Cape Parry and open water in Franklin Bay brought fog and heavy cloud that lasted for 35 days. In spite of 24 hours of daylight there was depressingly little snow melt due to lack of direct sunlight. Temperatures remained near normal (Figures 58, 59 and 60).

The amount of sunlight at Anderson River is controlled by wind direction and its influence on cloud and fog cover; wind direction is in turn dependent upon the condition of the sea ice (summarized in the Pilot of Arctic Canada). From May to September there is a track of low pressure systems which follow along the Arctic Coast. Location of this track north of the coastline has a profound effect on the

weather in Anderson River Delta. Winds from the northwest quadrant bring rain, snow and storm tides; at sea, the ice is forced in close to shore (Figure 37), causing local snow squalls at any time during a bad ice year. If the track is south of the coastline, prevailing winds are from the south, bringing good weather.

Figure 37. Beached sea ice in Liverpool Bay. (August, 1964.)

Microclimate of the Anderson River Delta: Within the nesting grounds, on the flats of the delta, the yearly variations in weather conditions affect the reproduction of geese. Probably the most important effect is the rate at which the nesting habitat becomes clear of snow and dries out enough to permit nest initiation and egg laying. The amount of snow trapped by vegetation and the contours of the goose flats on April 15 of any year, before any thaw begins, is

nearly constant. Superfluous snow is usually swept away to drifts along the channels or along the edges of the delta (Figure 38). Windblown snow is a common phenomenon during the winter and early spring. Yearly differences in snowfall are best shown in the snowdrifts on the edges of the delta, the edges of channels, and where willows have grown up on levees.

Within the nesting habitat, differences in vegetation, contour, etc. affect snow depth and hence snow clearance. The slight levees bare of willows, or sharp banks at the edges of channels where the wind can act are nearly always clear as a result of wind action. Old driftwood piles, fox dens and hummocks caused by ice push are among the first places to clear.

Bluff Island and the south end of Fox Den Island are often wind-cleared from the strong down-drafts over South Bluffs when prevailing winter easterlies are blowing. The faces of the bluffs are usually bare all winter. Also the fine silt of the weathered shales of the bluffs blow across the two islands and deposit a dark dust on the snow which absorbs heat and thaws the snow more quickly. The general southwest exposure of South Bluffs get more direct sunlight to melt the large drifts in the fluting. Runoff water always appears first on the ice around the low river islands at the base of the bluffs, and with its bare mud flats and grassy places it always attracts the first arriving pintails, whistling swans and white-fronts. Potamogeton strands frozen in the ice also absorb heat, hastening the thaw of river ice under the melt water. The wintered-over potamogeton, still relatively greenish-brown, is the major food of swans from their arrival in early May until after break-up in mid-July.

Figure 38. Snowdrifts against banks.

The flatter the nest habitat, the slower appears to be the progress of snow clearance. The outer islands which are the flattest and lowest are the last to show clear patches. Pacific brant which nest there are the latest nesters of the geese. In 1959, Brant Island never did clear in time for brant to nest in any large numbers. A heavy storm the fall before had apparently broken up the ice in Wood Bay, and a subsequent storm tide pushed large pans of it onto the island. This ice, about 10 inches thick and covered with snow, took a long time to thaw. The brant that could not nest there that season were forced to use habitat on the middle islands in the snow goose area with drastically reduced success due to fox predation.

Permafrost is at the surface when the thaw first begins. It remains within a half-inch of the surface during thaw in spite of melt water on

the soil. Once the soil is exposed to direct sunlight it absorbs much more heat, and the permafrost retreats about one inch by the time nesting begins.

Once the permafrost has thawed at least an inch it seldom refreezes. The nesting grounds at this time are soggy, and apparently absorb and hold enough heat to prevent refreezing in spite of the fact that early runoff puddles may refreeze.

By the time enough habitat has cleared to permit egg laying, the daily temperature fluctuations are much less than one would expect in arctic regions. Once the daily mean temperature has crossed 32°F, it seldom drops below freezing until fall (Figure 58), apparently because of the nearly continuous covering of water and mud, which ameliorates temperature changes, and the continuous daylight.

Precipitation is light during the thaw and egg-laying period. It usually occurs as light misty rain or fog. Snow squalls may be frequent in some seasons but the snow seldom accumulates, and it melts when it touches the ground.

Phenology of the Seasons: Table II gives data on the phenology of each of the summers of the study. Only those species for which I have the most complete data are shown. Other dates and remarks concerning the various species of plants, birds and mammals can be found in Appendixes A, B and C.

Some events are quite consistent from year to year, while others are variable. The variable events apparently are dependent upon the local weather conditions of a particular year.

Table II.

Phenology of selected events, Anderson River Delta, N.W.T.

Event	1958	1959	1960	1961	1962	1963	1964	1965	1966
Ice out	–	June 15	June 6	June 3	June 3	May 25	June 4	June 8	June 5
Snow, 4–6"							June 23–27		
Whistling swan arrival	–	May 16	May 14	May 15	May 18	May 15	May 16	–	May 13
White-front "	–	May 12	May 16	May 15	May 17	May 15	May 12	–	–
Snow goose "	–	May 17	May 19	May 16	May 18	May 15	May 18	–	May 17
Pacific brant "	–	May 24	May 26	May 23	May 28	May 25	–	–	–
Old squaw "	–	June 3	May 26	May 20	–	May 25	–	–	–
Marsh hawk "	–	May 18	May 14	May 16	May 18	May 18	May 17	–	–
Wilson snipe "	–	June 1	May 31	May 22	May 28	May 18	–	–	–
Glaucous gull "	–	May 12	May 12	May 15	May 17	May 16	May 12	–	–
White-crowned sparrow	–	June 5	May 29	May 22	May 22	–	–	–	–
Lapland longspur "	–	May 13	May 22	May 19	–	–	May 15	–	–
Snow goose migration peak	–	June 9	June 1	May 27	–	May 26	–	–	–
Swan, first nest	–	–	June 2	May 26	–	June 8	June 1	–	–
White-front, first nest	–	–	–	May 26	–	–	–	–	–
Snow goose, first nest	–	June 11	May 31	May 23	May 29	–	–	June 1	June 1
Brant, first nest	–	June 13	June 7	June 2	June 3	June 5	June 5	June 7	June 7

Table II (continued)

Event	1958	1959	1960	1961	1962	1963	1964	1965	1966
Swan hatch	–	July 17	July 6	–	July 20	July 6	–	–	–
White-front hatch	–	–	–	July 3	June 30	June 29	–	–	–
Snow goose hatch	June 24	July 6	June 26	June 20	June 24	June 18	–	–	–
Brant hatch	July 1	July 11	July 1	June 28	June 28	July 1	–	–	–
Swan molt	July 9	–	–	July 23	July 29	–	–	–	–
Snow goose molt	July 8	July 19	July 14	July 9	July 21	–	–	–	–
Brant molt	July 9	–	July 18	July 16	July 22	–	–	–	–
White-front young fly	–	–	–	Aug 9	–	–	–	–	–
Snow goose adults fly	–	Aug 5	–	July 27	–	all flying	–	–	–
Snow goose young fly	–	Aug 22	–	Aug 8	–	Aug 9	–	–	–
Brant adults fly	–	Aug 13	–	July 27	–	–	–	–	–
Brant young fly	–	–	–	Aug 8	–	–	–	–	–
Snow goose migration	–	–	Aug 18	–	–	–	–	–	–
Potamogeton on surface	–	July 23	July 13	–	July 15	July 7	–	–	–
Willow leaves yellow	–	Aug 21	–	Aug 18	–	–	–	–	–
Start of freeze-up:									
Coldest day	Sept 3	Sept 29	Sept 27	Sept 30	Sept 10	Sept 24	Sept 30	Sept 15	Oct 11
Heaviest snow	Sept 9	Sept 4	Sept 13	Sept 26	Sept 21	Sept 5	Sept 3	Oct 2	Oct 4

Arrival dates of swans, geese and hawks are probably more dependent upon day length than upon weather conditions in the general area. Some geese gather in huge flocks at staging areas: about 50 to 60 miles up the Anderson in 1965 there were 65,000 snows and 5,000 white-fronts; on the Mackenzie River in a stretch of sandy islands about 75 miles on either side of Little Chicago (at 67 12' N, 130 15' W, between Fort Good Hope and Arctic Red River) there were 130,000 snows and 15,000 white-fronts in the same year. The season in these protected valleys is much advanced compared to that of the arctic coastal nesting grounds within only a day's flight, either at Kendall Island, Anderson River Delta or even Banks Island.

Depending upon local weather conditions, the peak of migration onto the nesting grounds can vary as much as a week. Even so, in the very retarded season of 1959 at Anderson River, and in 1965 on Banks Island the snow geese stood around on the snow fields for up to three weeks before nesting, if they nested at all. On June 22, 1965, on Banks Island snow geese were gathered in large flocks on the southwest hillsides where they could get some food; their nesting grounds on the river flats were still nearly completely snow-covered. The nesting season in 1965 on both Wrangel and Banks islands, the two large producers of snow geese for the Pacific Flyway, was a complete failure because of local weather. This nesting failure quickly showed up in the adult-young ratios in the Pacific Flyway in the fall of 1965.

Other than Izembek Bay, Alaska, brant have no known staging area, except perhaps in leads off the north Alaskan coast. In spite of the great distance from Izembek Bay, brant arrive at Anderson River Delta on very consistent dates. They are known to be fast, strong flyers, and their migration to the nesting grounds must be largely synchronized by daylight.

Arrival dates of smaller birds, e.g. snipe and white-crowned sparrows, seem to be controlled much more by weather conditions along the migration route than are those of the larger waterfowl and hawks, and hence they are more variable from year to year.

Just about all of the events of the nesting season after the arrival on the nesting grounds are controlled by the weather conditions existing on the delta in that particular season (microclimate). The date of the start of egg laying and the date of the start of incubation are the most important weather-controlled events of the season for the geese. Subsequent events can be counted in the number of days until hatch, number of days to molt and regain flight, and, for the young, to start flying and become strong on the wing.

The date of a fall freeze severe enough to drive the geese out also can be a very important influence on their condition for migration. In 1959, a late spring, the few geese that did nest, still had some flightless young when a freeze and snow covered the land September 4. The birds that did get away were in poor condition for long migration flights. Brant and swans which feed on the potamogeton beds in the river channels or on coastal grasses and carex were less affected, and could hold off migration until closer to the final freeze-up, September 18. Even so, many swans were caught by the freeze that year.

In more normal seasons most geese and ducks are strong on the wing before the first of September. Those that are late in regaining flight, including swans, scaup, old squaws and scoters, usually congregate on larger bodies of water, river channels or at sea where the freeze-up occurs later.

The Geese of the Anderson River Delta

PACIFIC BRANT

Branta bernicla nigricans, also known as the black brant, Pacific brant, sea goose, Eskimo goose, nuglingnuk, etc., is a small dark goose weighing about 2 1/2 to 3 1/2 pounds. On the wing it appears short-necked and duck-like. However, its wings are long in proportion to its body, and it is probably the most agile flyer of any of the geese.

Branta bernicla is a circumpolar species, inhabiting suitable nesting grounds all around the Arctic Ocean and as far north as land extends (northern Ellesmere Island). The three subspecies (Pacific brant; Atlantic brant, *B.b.hrota*; and European brant, *B.b. bernicla*) may be in the process of becoming distinct species by virtue of partial geographical isolation on their nesting grounds and nearly complete isolation on their wintering grounds. The important aspect of this geographical isolation is the fact that mates are selected mainly during migration and on the wintering grounds when the subspecies are on opposite sides of continents or oceans. Mating and copulation many miles from the nesting sites may explain why Pacific and Atlantic brant rarely cross-breed, although their breeding ranges overlap at Queen Maud Gulf, Melville Island and Prince Patrick Island.

Pairing or mating in brant takes place over a long period of association, perhaps one or two years, before maturity. Three-bird chases begin among yearlings just prior to and after the annual molt which occurs on the fringes of the major nesting colonies and in separate molting places frequented by yearlings and failed breeders. These

three-bird chases increase in frequency on the wintering grounds, among only a fraction of the population, the non-paired element (Einerson, 1965). Once I had the good luck to collect all three birds of a three-bird chase. The lead bird was a one-year-old female, closely followed by a two-year-old or adult male and a yearling male. The chase had been underway for about eight minutes, a zig-zagging, dipping and rising flight from horizon to horizon before I was able to make the kill near the take-off point. The female was the lead bird throughout the chase.

Sub-adult or immature birds tend to stick together in flocks or sub-groups which are probably formed by age classes when the family groups begin to break up in October or early November. Robert Jones (personal communication, 1966) reports the marked change in intra-flock aggressiveness during their stay at Izembek Bay in October. He believes that by the time the migration across the Gulf of Alaska and the North Pacific to California begins, the family group has largely broken down.

Band recoveries of both Atlantic and Pacific brant confirm this age separation in that the young show up in comparatively larger numbers at the southern extremities of the winter range. It is true that some family groups stay intact until incubation begins the following season (this can be noticed most frequently in Atlantic brant), but it can be assumed that, for the most part, age-group flocks are formed when the young are about four months old and the entire Pacific brant population is gathered in one pre-migratory flock at Izembek Bay. It is through long association in these age-group flocks that the pair bond is formed. By the time the flock returns to the Arctic to molt, it is probably a tightly knit organization having little truck with others of its kind should they by chance meet in some molting place.

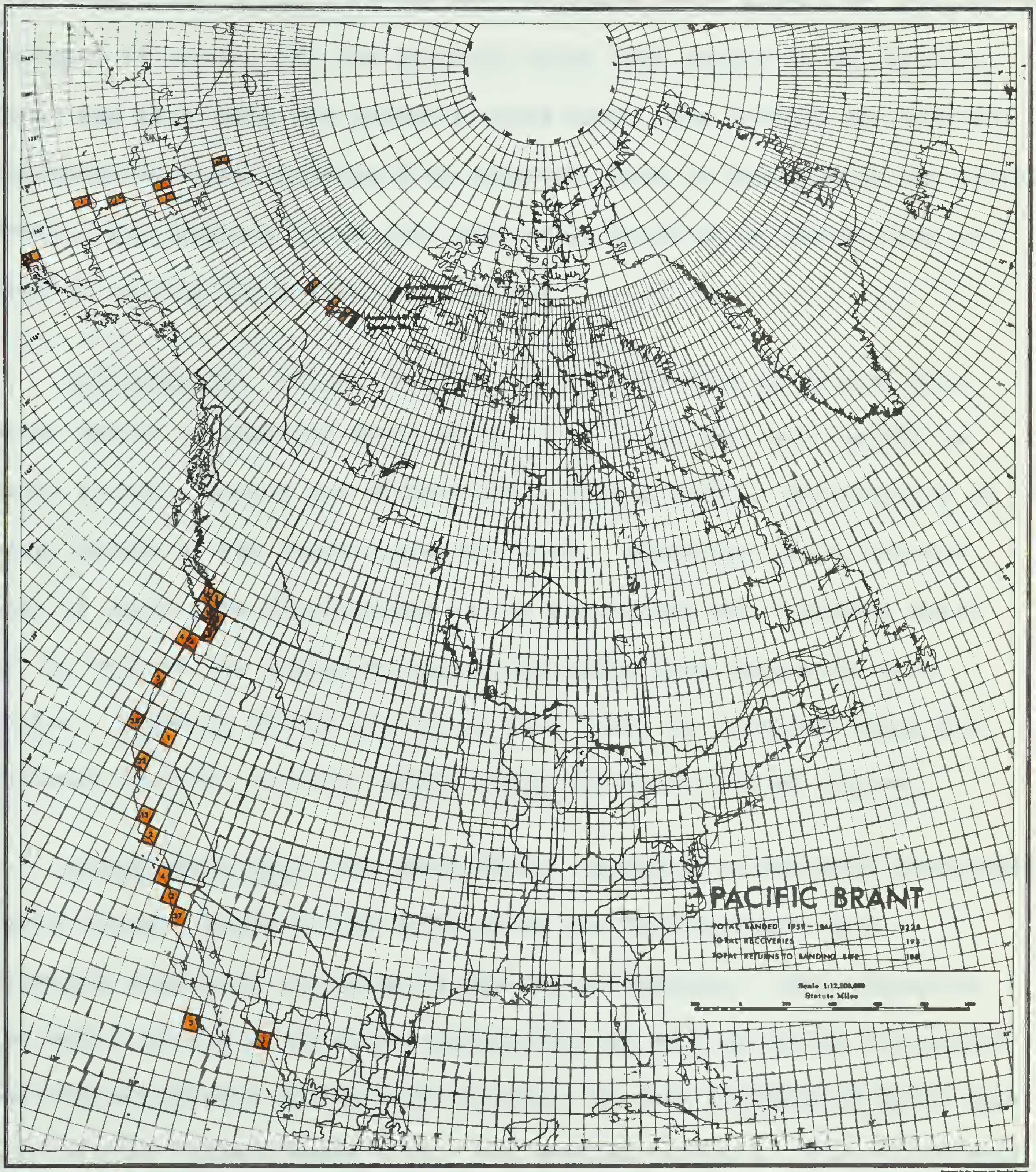


Figure 39. Pacific brant distribution map.

Bonds are further cemented during a second yearly migration, and in the third year when the birds finally nest. Band recoveries indicate that brant live in the wild at least 10 years after adulthood, or a total of about 13 years. The few Atlantic brant that wander to the Pacific Coast and vice versa are probably quite rare. The chances are that the instances of cross-breeding I've observed, both in the eastern and western Arctic, are immature birds that eventually mated or of adults from an area of overlap which lost their mates.

Distribution: Figure 39 shows the distribution of returns from brant banded at Anderson River Delta, plus a few that were banded on Banks Island. Hansen and Nelson (1957) show a similar distribution of brant banded at the Yukon-Kuskokwim Delta. Wintering ground surveys made by Smith show fluctuations in the population and a gradual shift of the bulk of the wintering population south from California into Mexico. Einarson (1965) attributes this shift to increased human disturbance in their favorite haunts along the Pacific Coast states.

Spring Migration: The adult Brant, including a few still observable family groups, begin moving north along the Pacific Coast in a leisurely migration beginning in January or February. This migration has been reported by observers personally, as well as in the literature and from occasional spring band returns. By late February or March they have reached the northwest states and British Columbia. From there some continue up the inside of Vancouver Island and skirt the Alaskan coast to arrive at Izembek Bay (55° 15' N, 162° 45' W) in late April or early May. Others apparently head around Vancouver Island and across the North Pacific and Gulf of Alaska to Izembek Bay. Many of the non-breeders

and adults that wintered further south probably trend away from the coast toward Izembek Bay from points as far south as northern California. By early May the bulk of the Pacific brant population is apparently gathered at Izembek Bay.

From there many make the rather short trip to the Yukon-Kuskokwim nesting grounds. For many others, including the Anderson River Delta birds, Izembek Bay is but a half-way point in their long migration. Up to this point the migration has been rather leisurely, and the birds presumably have been building up fat reserves.

With the lengthening daylight the tempo of the migration steps up, and flights are long and almost continuous. Because the advance of continuous daylight proceeds south from the North Pole to the Arctic Circle, the brant are in continuous daylight by May 20 to 26 when they reach the Arctic Coast of Northern Alaska or Siberia.

Brant follow the coast to traditional nesting grounds as far east as Queen Maud Gulf, or branch off across the Beaufort Sea to Banks Island and the high arctic islands northeast to Ellesmere. Russian drift station personnel have spotted a flock of brant 300 miles out over the arctic pack ice heading northeast, toward Ellesmere or one of the Ringnes islands.

The last groups of adults to leave Izembek Bay are presumed to be Arctic Coast birds rather than the earlier nesters of the Yukon Delta. Judging from departure dates at Izembek Bay, they make this final flight of one to two thousand miles to their nesting grounds in only three to six days, flying as if under the influence of the continual daylight rather than weather conditions. Arrival dates at Anderson River Delta vary only by a day or so from season to season; this is so regardless

of the snow cover or weather conditions on the nesting grounds. I have also found this to be true for Atlantic brant of Southampton Island.

Some brant do not follow the coast of Alaska around to their nesting grounds. Cade (1955) describes a route up the Yukon River and through such passes in the Brooks Range as Anaktuvuk Pass to the arctic coast. Brant are familiar to the Indians of Old Crow Flats, Y.T., suggesting that some undoubtedly continue up the Yukon and cross the Richardson Mountains, perhaps by way of the Rat River Pass, though more likely at Blow River, to reach the Mackenzie Delta and the arctic coast.

Pacific brant arrive on the nesting grounds quite consistently about May 25. They appear from the north, from Cape Dalhousie across Liverpool Bay, around Nicholson Island and across Wood Bay, as do other coastal migrants including arctic and red-throated loons, king eider, old squaw, glaucous gulls and many of the shore birds. Arrival of brant after their long flight is, as with other geese, a quiet, unclamorous event. Generally the male flies ahead of the female if they fly in a line, although line formation is very rare among migrating brant. They settle onto the snow fields or bare patches of the outer delta and remain quiet and sedentary for a day or so. Their nesting habitat is seldom ready for them on arrival. What bare patches have appeared are soupy mud or soggy turf, covered with melt water or river overflow.

<u>Nesting Distribution</u>: The general distribution of nesting Pacific brant is summarized in the AOU Checklist (1931), Einarson (1965); Barry (in press) and others. They nest mostly in selected coastal habitat from Queen Maud Gulf north to Ellesmere Island, west to New Siberian Islands, and south to the Yukon-Kuskokwim Delta. They prefer low coastal deltas and islands but can be found scattered on inland lakes

such as on Banks Island. They are generally loose colony nesters on suitable habitat, but can be widely scattered in more marginal conditions.

In the 1958 and 1960 surveys covering the Arctic Coast from the Alaska Boundary to Boothia Peninsula, north to Somerset and northern Baffin islands, and west to Banks Island and all islands between, I was struck by the number of suitably vegetated habitats that were unused, possibly because they were not broken up into islands and deltas. Also, brant are very traditional (philopatric); they are not likely to pioneer new nesting grounds unless their population grows considerably larger than it is today.

Summer distribution of non-breeders falls generally within the breeding range. Often the non-breeders stay on the fringes of the larger concentrations. Many others use the coastal turfs already mentioned as well as gravel beaches and mud flats.

Only six of the 10,000 brant banded as young at the Yukon-Kuskokwim Delta have turned up among the birds handled at Anderson River Delta. Likewise, only three of the 3,000 Anderson River brant have been recaptured among nesters in Alaska. There is apparently very little interchange between nesting populations, probably less than one per cent.

In our own operations, 40 per cent of the adult Pacific brant neckbanded at Anderson River Delta returned to their nesting grounds one year later. This compares well with the 38 per cent of Atlantic brant returning to the Boas River, Southampton Island, in 1957 (Barry, 1962). Average annual adult brant recapture~~d~~ RATE is 14. 7 per cent, but the recapture rate depends on where we locate our banding corrals from year to year, as certain birds tend to use certain parts of the delta for certain purposes, e.g. molting brant at Kettlehole Point.

The number of brant banded as downy young which return to the nesting grounds with the family group or as individuals is small for the first two years (15 per cent at one year, 10 per cent in their second year); there is a marked increase to 55 per cent in the third year when most of them return as adult nesters. The figures for four and five year olds (10 per cent each) are probably not very reliable because of loss of bands to corrosion by the sea water of the brant's usual habitat.

Reproduction: Most brant first breed when they are three years old. In good seasons there is some evidence that some two-year-old birds are successful nesters, perhaps 10 per cent of them.

Within a day or two of arrival, brant begin exploration flights over the outer and middle delta. They are paired but remain in flocks which in time get smaller and smaller, except for the main roosting flocks in the outer delta.

By about June 2, the brant migration is over, and the flocks become more clamorous. Pairs fly over the outer delta in search of nest sites. In these low skimming flights the female leads, followed by her mate. In a few days they are scattered in pairs over the available habitat.

Size of the nesting territory is variable depending on how much suitable nesting habitat is available: a small lone hummock in the middle of a vast mud flat or turf can be the center of a territory several hundred yards across. Yet a 40 by 20 foot hummock surrounded by flat wet turf on the outer edge of Oil Drum Island had seven brant and two snow goose nests on it. At the start of egg laying the territorial fights there amounted to a nearly continuous brawl.

Brant Island, which appears to be the optimum habitat, is an interspersion of mud flats, grassy clumps or hummocks, small shallow sloughs and puddles and a turf of brant grass (_Carex subspathacea_) and _Puccinellia phryganodes_, it is gathered into the nest rather sparingly. Brant grass grows thicker and faster around the nest, probably the effect of the bird's body heat. Table III summarizes the nest material used, and its relative abundance in brant nests.

Figure 40. Female brant on nest.
Photo by Cy Hampson.

The nest is first formed as a scrape or bowl-shaped depression which the female makes by scrunching and twisting her body down into the soggy turf. She uses her feet to push aside the soil until she meets permafrost about 1 to 1-1/2 inches down. As egg laying progresses, nest material and down are added so that the nest is completed by the time all the eggs are laid and incubation begins (Figure 40).

Table III. Pacific brant nest material and use of down.

(Percent of nests in which material is used)

	"Grass"*	Willow** leaves	Willow twigs	Juncus***	Driftwood	Old Nest
1959 108 nests	97.2%	20.4%	17.6%	3.7%	8.3%	nil
1960 107 nests	95.3	22.4	17.8	0.9	6.5	15.9%
1961 35 nests	100	14.3	14	10	nil	28.6

* *Carex subspathacea* (a sedge), *Puccinellia phryganodes* and *Elymus arenarius*

** *Salix arctica*

*** *Juncus balticus* var. *alaskanus*

Egg at which down is first supplied during laying

(percent of nests)

Egg No.	1	2	3	4	5
1959 36 nests	25.0%	55.5%	16.7%	2.8%	-
1960 96 nests	7.3	26.0	27.1	28.1	11.5%
1961 20 nests	33.0	16.7	33.0	16.7	-

Nest measurements of Atlantic brant (whose nests are similar to those of Pacific brant except for some of the materials used) are summarized in Barry (1960). The nest depression is barely above melt water levels, and standing water is often nearby. Occasionally the first egg is laid in water on top of the permafrost. Table IV shows the relation of standing water, snow and tide water to the nest site.

Copulation possibly occurs at the Anderson River Delta, but I have not seen it. More likely, it takes place earlier at some rendezvous point far removed from the nesting grounds, so the birds are ready to nest as soon as they arrive. The presence of cleared habitat seems to be an environmental stimulus to start nesting (Serventy and Marshall, 1957; Barry, 1962).

The egg-laying period for brant is about 10 days. They are determinant layers and will not re-nest EXCEPT at a nearby site to complete the clutch. Usually four to five eggs are laid, one each day, but often with a skip of a day; the skip is most frequently between the second and third eggs (Cooch, 1953; Barry, 1962). Eggs are usually laid in the morning, but in continuous daylight this does not seem to be very consistent.

If there has been much rain or excessive melt water flooding during egg laying, the first eggs may become coated with sticky mud. Once dried it may hamper hatching and sometimes actually prevent the gosling from emerging from the shell.

Incubation begins when the last egg is laid. The first eggs remain dormant until incubation begins so that all eggs hatch within a few hours of each other, even though they were laid over a period of five or six days. Incubation time, from the day the last egg is laid until the first

Table IV. Proximity of brant nests to snow and water.

Height in inches of nests above normal high tide line or standing water (at start of nesting)

	1959 (108 nests)	1960 (107 nests)	1961 (35 nests)
Average	5.7	6.6	8.1
Lowest	0.0	0.0	1.5
Highest	24.0	36.0	36.0

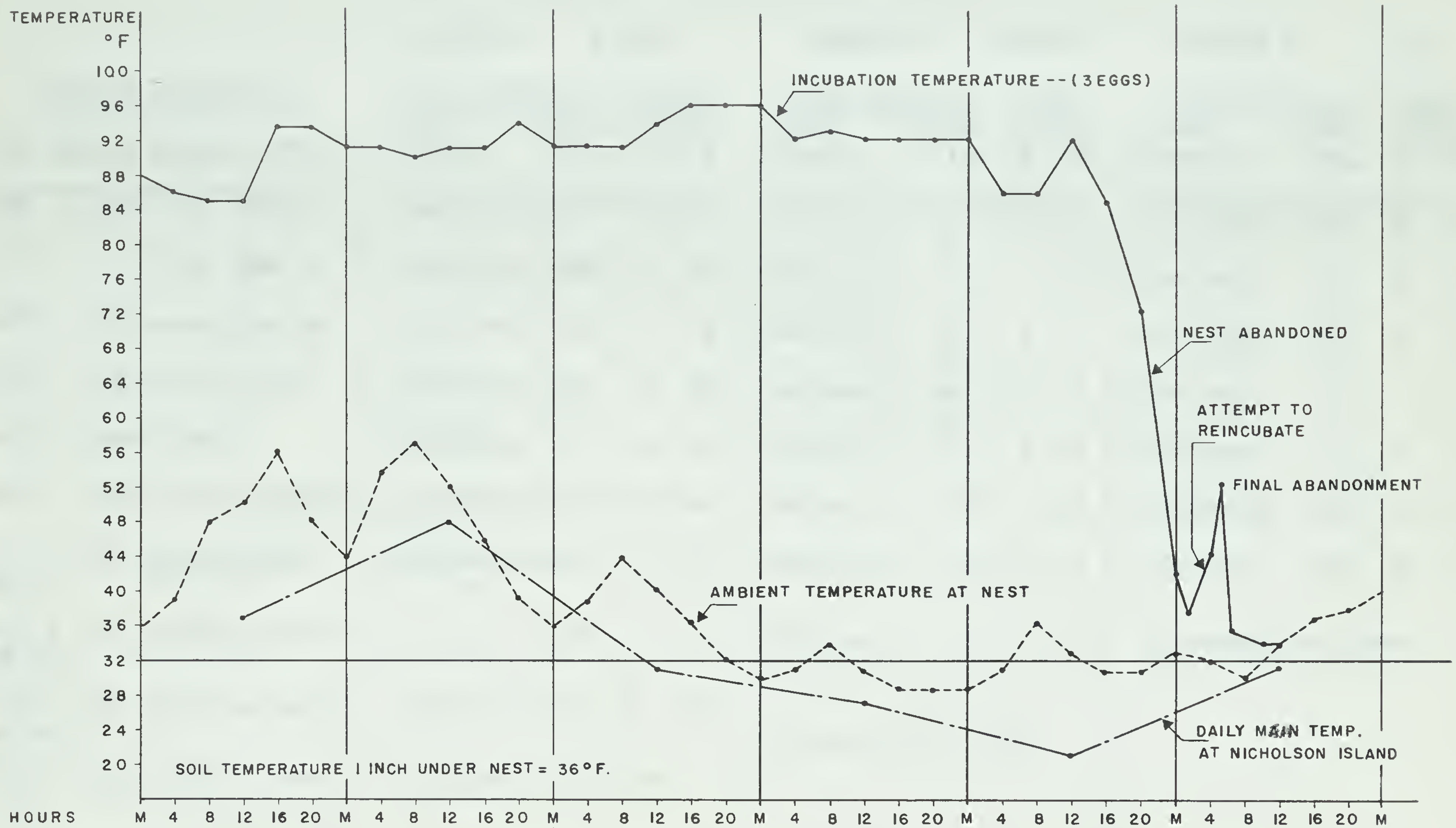
	Distance in feet of nests from snow cover 1959 (108 nests)	Distance in feet of nests from standing water 1959 (108 nests)
Average	20	10.6
Closest	1	0.0
Furthest	100	100.0

egg hatches, averages 24 days. By the time she is ready to incubate, the female has completed her nest and has lined it with a down that is cohesive and luxuriant. The female brant has a large brood patch, as is the case with almost all arctic nesting birds. On brant, this patch is about the size of a man's hand, and both contour feathers and down are plucked exposing bare skin.

Using thermistor probes attached to the eggs and micro-switches implanted in the nest, we could record the incubation temperature and the female's activities on and off the nest relative to the ambient temperature and weather conditions. Figure 41 and Table V summarize the activity and temperature records made of incubating brant during a period in 1964 that led up to violent winds and a snow storm resulting in abandonment of most brant and goose nests in the delta. Of particular interest are the long periods the females are off their nests while the incubation temperature is maintained by down insulation. But once the down and soil become wet and soggy the female can no longer maintain incubation temperature and the nest is abandoned.

Only the female incubates, while the male waits nearby in the territory or common ground. He often calls the female from the nest in case of danger, and usually he escorts her to and from the nest to feed. During these escorts he seldom approaches any closer than about 15 or 20 feet from the nest. On feeding trips the female always leaves the eggs covered with down. When frightened she flushes directly from the nest or runs off calling continuously, leaving the eggs uncovered.

When the nest is under mob attack, by two to six diving parasitic jaegers (Stercorarius parasiticus) or by a fox, the male brant comes up to the nest and stands opposite the female as they face the attackers.



DATE	22 JUNE 1964	23 JUNE 1964	24 JUNE 1964	25 JUNE 1964	26 JUNE 1964	27 JUNE 1964
WEATHER	CLEAR	CLEAR → LIGHT RAIN	RAIN → SNOW .34"	SNOW .30" DRIFTS 6"-10"	SNOW .08" DRIFTS 8"-12"	MISTY RAIN .01" → CLEARING
WIND	S.E. 5 M.P.H	S-SE 10-15 → CALM	N.W. 20, GUSTS 30	N.W. 35, GUSTS 50	N.W. 30, GUSTS 55	N. 5 TO CALM
♀ ACTIVITY	OFF NEST 40 MIN.	OFF NEST 70 MIN.	OFF NEST 30 MIN.	ON NEST ALL DAY	OFF NEST 110 MIN.	NEST ABANDONED 0500

FIG. 41 TEMPERATURE OF INCUBATING BRANT DURING UNSEASONAL STORM IN 1964

Table V. Fate of brant nests during unseasonal storm.

June, 1964, Anderson River Delta, N.W.T.

Date	Weather Conditions: Av. Temp.; Precip.; Wind	BRANT 1: 4 eggs — Time off Nest: Usual Period	BRANT 1: Total Min.	BRANT 1: Movements A	BRANT 1: Movements B	BRANT 2: 3 eggs — Time off Nest: Usual Period	BRANT 2: Total Min.	BRANT 2: Movements A	BRANT 2: Movements B	BRANT 3: 4 eggs — Time off Nest: Usual Period	BRANT 3: Total Min.	BRANT 3: Movements A	BRANT 3: Movements B
18	38° ; .04" rain; NW 10	1500-1800	440	20	16	Not reg.	80	10	31	1600-2000	300	16	18
19	37° ; .3[illegible]" rain; WNW 15	1500-1900	260	11	16	Not reg.	90	4	30	Not reg.	60	3	13
20	40° ; .02" rain; NNW 10	0700-0900	370	*	5	Not reg.	90	9	27	Not reg.	70	4	10
21	33° ; .01" rain; calm	1800-2000	200	12	15	Not reg.	140	11	21	Not reg.	70	3	11
22	47° ; clear; SE 5	0100-0400	370	13	15	Not reg.	140	9	32	Not reg.	60	6	13
23	48° ; clear > rain; SE 10	2400-0300	500	23	14	Not reg.	230	9	32	1400-1600	250	10	25
24	37° ; .34" rain > snow; NW 20	0100-0600	400	2	9	Not reg.	110	12	16	Not reg.	70	6	4
25	31° ; .30" drifting snow NW 35	-	30	3	1	Not reg.	30	5	10	Abandoned nest 0900			
26	33° ; .08" drifting snow; NW 30	1300-1700	770	**	18	Abandoned nest 2000	270						
27	31° ; misty rain > clear; N 5	Abandoned nest 0030											

A= No. of times eggs shifted
B= No. of comfort movements

*continual shifting for $1\frac{1}{2}$ hr., probably to dry out nest.
**continual shifting for $7\frac{1}{2}$ hr., for same reason.

Table V continued.

Date	Weather Conditions	BRANT 4: 4 eggs				BRANT 5: 3 eggs				BRANT 6: 4 eggs			
		Time off Nest		Move-ments		Time off Nest		Move-ments		Time off Nest		Move-ments	
	Av. Temp.; Precip.; Wind	Usual Period	Total Min.	A	B	Usual Period	Total Min.	A	B	Usual Period	Total Min.	A	B
18	38°; .04" rain; NW 10	0400-0900	940	15	25	1400-1200	1230	7	30	0100-1100	1210	16	30
19	37°; .31" rain; WNW 15	0400-1000	1060	10	18	2400-0900	1180	11	17	0100-0900	1190	8	27
20	40°; .02" rain; NNW 10	0800-1030	690	33	22	0200-0900	1160	11	24	0100-0900	1200	17	26
21	33°; .01" rain; calm	0400-0600 0800-1200	790	6	8	0200-0700	1130	19	29	0300-1000	1160	6	22
22	47°; clear; SE 5	0300-0600 1200-1500	820	17	9	0300-0800	1190	8	39	0400-1200	1200	9	27
23	48°; clear>rain; SE 10	0900-1700 1900-2300	1090	17	15	0300-0900	1190	7	31	0500-0800	1140	10	28
24	37°; .34" rain>snow; NW 20	0400-1200	640	8	10	0100-0200 Abandoned nest 1600	1160	9	15	Abandoned nest 0130			
25	31°; .30" drifting snow; NW 35	Abandoned nest 0300											
26	33°; .08" drifting snow; NW 30												
27	31°; misty rain clear; N 5												

A= No. of times eggs shifted
B= No. of comfort movements

They utter a low menacing growl with bill agape and head and neck poking towards the intruders.

The parents become very defensive when the young start to pip. Often they will stand over the nest with wings outstretched and will attack anything or anyone approaching them.

It takes about 24 to 48 hours for all the eggs to pip, hatch and for the young to dry. If the weather is particularly cold or blustery this hatching period may take up to 72 hours. Even then, the female may continue to brood the young on the nest until the weather clears. Usually the young are called from the nest as soon as they are dry. If disturbed, the dry young, able to walk, are called from the nest at once and the rest are abandoned. Hatching success of brant is very high; only a small percentage of eggs are infertile, abandoned or lost in various ways (Sherwood, 1961; Barry, 1960).

As soon as the young are dry, the male takes over the dominant role in care of the young (Figure 42). At this time the male is usually in the lead, followed by the young and then the female. The female has lost considerable weight during the incubation period, while the male has regained much of the weight he lost during the territorial defense of egg laying and early incubation (Figure 51).

Around the family there is a small mobile territory which is vigorously defended as the family swims or feeds. This territory becomes smaller as the young lose their down and begin developing flight and body feathers, at about two weeks of age, but it persists after feeding flocks have formed and even well into migration. Brant arriving at Izembek Bay are still in family groups. By the time they have gained weight and are ready to continue migration in late October or early

November, the family group has dissolved (Jones, 1964, and personal communications, 1966).

Figure 42. Brant in family groups, males in the lead.

Until about one week after the hatch, it appears the parent brant are unable to recognize their own eggs or young, and the week old young are unable to recognize the parents. Often we have put abandoned young into a hatching nest and they were accepted. Abandoned wet young that dry out and become mobile on their own are often able to attach themselves to a passing brood, but after about a week's time parent birds peck and drive away any stray young that are not one of the family.

In the continuous daylight the young feed almost constantly except for brief periods of brooding. Their growth rate is very fast, similar to that of other arctic geese. They are able to walk when dry or within

about four to 12 hours of emerging from the shell. They swim as soon as they can walk, and can dive well when two days old. By 10 days, they can maintain themselves without brooding by the parents. Flight feathers emerge on the wings at about the same time, and the down is replaced by body feathers beginning with the head and neck. By 40 to 45 days the young are able to fly; this is around August 15 in normal seasons, but varies depending on early or late seasons.

Molt: Molt of non-breeders appears to be at a constant time, beginning about July 4. It is part of the yearly cycle that is apparently controlled by day length.

The brood patch on the females begins to be replaced by thick down after the young hatch. By 10 days after the hatch her belly is covered with a steel-gray down about 1/4 to 1/2 inch thick, and breast feathers are beginning to appear.

The annual molt of flight feathers of the parent begins about two weeks after the young have hatched. The date of this molt is variable, ultimately controlled by the date incubation starts and hence by the habitat conditions at the beginning of the season.

The annual molt of the male appears to be more consistent than that of the female. It appears that if the season is early the female molts before the male by several days. If the nesting season is late the male molts first by several days. I have only casual observations to support this, however.

Brant that cannot nest by a certain date in June because of habitat conditions resorb their ovarian follicles, skip the days of egg laying, incubation and hatch, and proceed as soon as physiologically possible into the molt (Barry, 1962). Brant apparently prefer not to nest

rather than push on to other nesting grounds. Brant do not re-nest, and if the clutch is destroyed the parent birds molt earlier than the successful breeders but later than the non-breeders.

The flightless period of the parents is only about three weeks, so they are capable of flying when the young are about 35 to 40 days old, although they seldom actually do until the young are also ready. The gregariousness of brant, or their strong parental ties, is shown when we herd flightless brant into pens for banding: adults which have recently regained flight will frequently fly out of the pen, circle and then land back in the pen again where we still can catch and band them.

Molt migrations along the shores by both non-breeders and adults with young can spread them at considerable distances from their starting point. Some non-breeders I banded at the Smoke and Moose River flats in Kugaluk River estuary were recaptured six days later, 65 miles away, at Middle Creek on Wood Bay.

Fall Migration: The fall migration of the brant is pretty much a reversal of the spring route, except that it is almost entirely coastal around Alaska, with ~~with~~ little evidence of a flight back down the Yukon River system. This allows the brant to take advantage of the food and shelter of the open bays on the Arctic Coast all the way to Izembek Bay. Hansen and Nelson (1957) describe two waves of migrants into the bay, one in September, presumably from the Yukon Delta, and one in October, presumary from nesting grounds along the Arctic Coast and islands.

Preble (1908 p. 308) states: "Through keeping stricly to the sea-coast east of the Mackenzie during migration many of the flocks

(probably of the eastern breeding birds) strike across Alaska from near the mouth of the Mackenzie to the North Pacific." This was probably mostly conjecture on his part, but not entirely unreasonable. The coast-loving brant do make long overland flights. My banding results for Atlantic brant show that the bulk of that population makes a migration flight, usually non-stop and at high altitude, from James Bay and southern Hudson's Bay directly to coastal New Jersey.

Such overland flights for Pacific brant are possible, though not extensive or necessary because of lack of food. Nevertheless, on September 15, 1963, while checking the fall migration of waterfowl in the Mackenzie Valley, I came upon a flock of 75 brant in the river near Norman Wells, and another flock of 150 on Keele Lake in the Mackenzie Mountains about 500 miles from the Arctic Coast and 600 miles from the North Pacific. A storm the day before may have forced them down before they could cross the mountains.

Because brant are largely coastal migrants and because the Arctic Ocean and its bays and lagoons do not freeze until late October, brant can begin their move westward along the coast in easy stages even while the young may be weak on the wing, and they can still find abundant food and resting spots. For two days in late August, 1965, we observed about 225 brant resting at the base of a sandspit where a thick turf of brant grass had established. Ten of them wore red neckbands we had put on them at Anderson River two weeks before.

In late nesting seasons, the later average date of freeze-up on the coast gives the brant an advantage over the snow geese, which are inland migrants and more subject to being frozen out.

LESSER SNOW GEESE

According to the latest taxonomic revisions by Cooch (1958 and 1961), the snow goose is only a color phase of the blue goose (*Chen caerulescens caerulescens*) and not a subspecies (*C.c. hyperborea*) as used by Manning, Hohn and Macpherson (1956). Nevertheless, in the western Arctic the blue phase is seldom seen and people will continue to call the birds snow geese for some time.

Distribution: The snow geese of the Anderson River Delta are part of the Pacific Flyway population, as are the Banks Island, Kendall Island and Wrangel Island snows (Teplov and Shevareva, 1965; Kozlik, Miller and Rienecker, 1959). They winter in the Sacramento Valley of California south into the western states of Mexico (Figure 43).

Spring Migration: During the last half of March the adults move north into concentrations at Tule Lake and the Klamath Basin of northern California and southern Oregon, and into the Malheur Refuge Area in east central Oregon. They follow the snow clearance by a week or so as they cross the continental divide into west central Montana and southern Alberta.

By April 20 the first flocks reach central Alberta where they feed in the grain fields until early May. So far the migration has been leisurely, with much time spent on feeding and fattening up. The last half of the trip to the nesting grounds is made much faster, with fewer stopping places. Eventually they overtake and pass the northward progress of spring thaw.

By the first week of May some of the flocks stop at Hay Lakes in northeastern Alberta or in the Slave River Delta on the south shore of

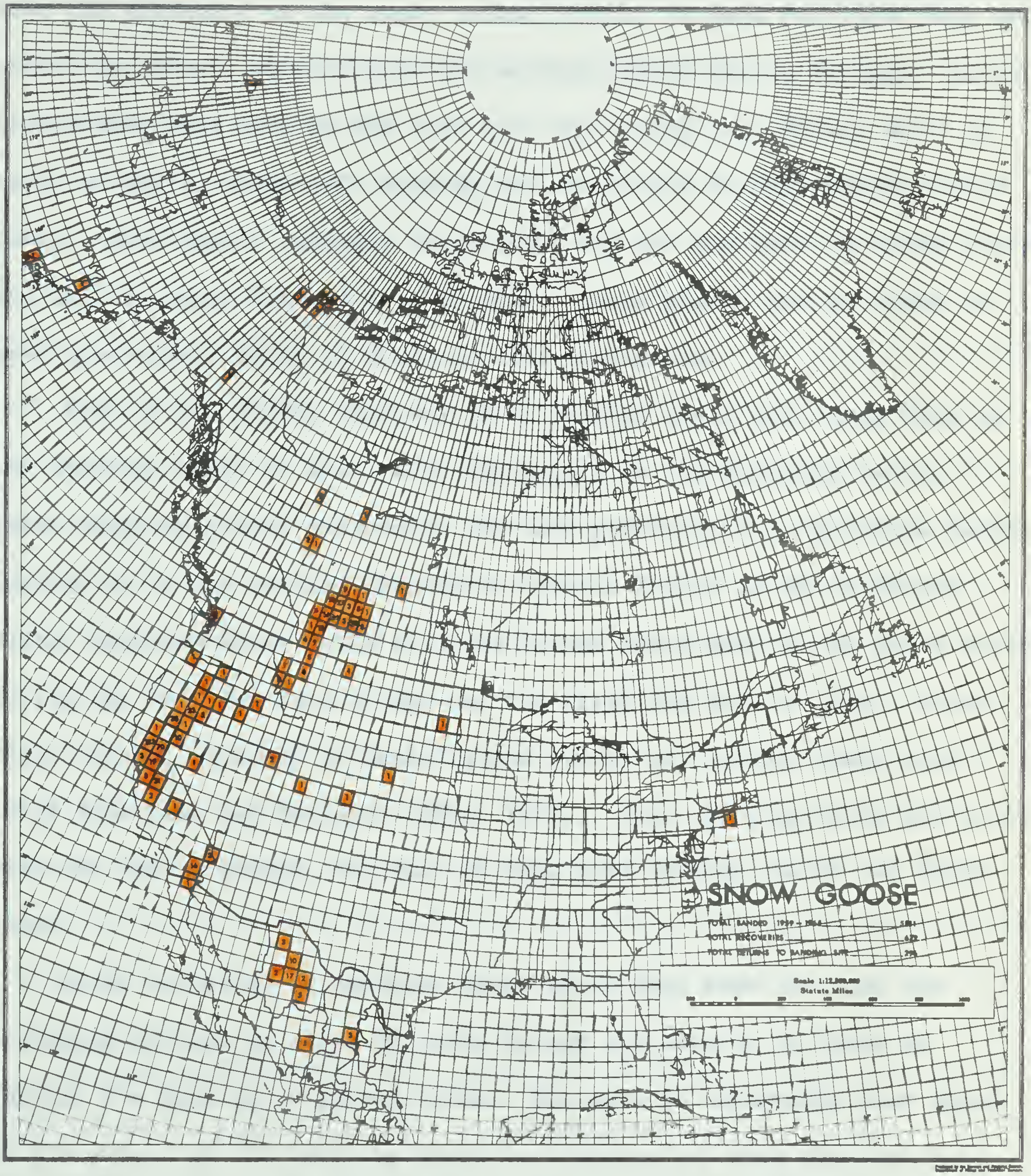


Figure 43. Snow goose distribution map.

Great Slave Lake. Most of the flocks continue on in a north-northwesterly direction, parelleling the Rocky Mountains to the Mackenzie Valley, then down the Mackenzie to the sandy island stretch between Fort Good Hope and Arctic Red River, particularly the section around Little Chicago. Large flocks have been seen on the sand bars and flying over Norman Wells as early as May 6, apparently heading for the Little Chicago concentration point. Here runoff channels form early, and the mud bars and sandy flats are usually swept free of snow by wind. These places are the first to have open water, which is necessary for copulation.

Some of the flocks continue on to similar areas near Windy Bend in the Anderson River or near Point Separation in the Mackenzie Delta. These stopping places presumably are used primarily for copulation before pushing on to the nesting grounds on Kendall Island in the Mackenzie Delta, Anderson River Delta or Banks Island where most of the geese arrive during the last few days of May and the first few days of June. Other minor routes, probably of Banks Island birds, are further east, over Great Bear Lake and Paulatuk (Höhn, 1959). Some yearling birds are still with the family groups, but most of them pass through one or two weeks later.

Birds collected at Anderson River where they pass low over the ptarmigan willows en route to Banks Island are usually in lines or partial V's made up of paired birds. The male is invariably just ahead of his mate. If the last two birds of a string are shot the last one has always been a female, the one just ahead, its mate. If the female is shot, the male will drop out of the flock and will circle the spot where his mate fell for up to three hours. If the male is shot, the female drops out and circles her mate a few times before hurrying to catch up

with the flock. This behavior, which I have seen repeated many times, indicates that the female has already been fertilized and that it is possible for her to push on to the nesting site and nest alone, although with less chance of success than with her mate. Brant and white-fronted geese have the same behavior.

Once when I crippled a female, she flew on for about 1-1/2 miles before she landed. Her mate landed in the snow beside her. When I approached, they went through the peculiar behavior of nest defense which I have seen only when the young are hatching: the female straddled the "form" in the snow where she had been sitting; it was much like a nest depression. She held out her wings and threatened me with her head held high and crooked, uttering a low "baa-ing" call. She interrupted this by poking her head down between her legs to the "nest form." The male stood close beside her, his wings out, head and neck pointed up at a 45 angle, bill agape, threatening me with the same call. He would run from side to side of his mate and occasionally led away with his wings still widespread. When I was about 15 feet away the female attacked, and gave me a terrific lashing with the wrists of her wings. It seems that even before nesting begins geese may defend the urge to complete the reproductive cycle.

Nesting Distribution: Snow geese of the Pacific Flyway nest in two large colonies, each with smaller independent satellite colonies. The two large colonies, on Banks Island in northwestern Canada and Wrangel Island in the USSR, form the major components of the two populations migrating to the California and Mexico wintering grounds. Band returns indicate that there is some interchange between these two major colonies, and somewhat more between the major colonies and their satellites.

Snow geese banded at Anderson River have been recovered at Banks Island, the satellite colony at Kendall Island and at Wrangel Island. Birds banded at Banks Island have been recovered at the other colonies, while Wrangel Island bands have appeared near Tuktoyaktuk, an important spring migration pass towards Banks Island. Some blue geese show up at Anderson River, where one was mated to a snow goose in 1963 and 1964, and at Kendall Island where another was mated to a snow goose in 1957. From 10 to 20 blues were seen on each of our Banks Island surveys of 1960, 1961 and 1962.

I specify the Banks Island and Wrangel Island colonies as the major colonies not only because of their numbers (150,000 and 350,000 respectively), but also because they seem to be the base for non-breeding birds in the molt. Thomsen River and Castel Bay on northern Banks Island is a major molting area of non-breeders. Although Uspenskii (1963) indicates most non-breeders do not return to Wrangel Island, they probably are in the vicinity on the nearby mainland, perhaps at Kolyma River, etc.

It is possible for the two major colonies to have simultaneous reproductive failures because of late spring with persistent snow cover (as in 1965). At the same time, the satellite colonies might have good reproduction because they are far enough removed to have different local weather patterns. It is also possible for one major colony to have a good season while the other has a poor season.

Reproduction: Most snow geese first breed when in their third season. In particularly favorable seasons, some may breed when two years old. Our nesting ground band recovery data shows that no geese banded as young are recaptured as one-year-olds at the Anderson River,

but that 17.1 per cent of the geese banded as young are back on the nesting grounds in their second year. There is a 51.5 per cent return in their third season and 31.4 per cent return in their fourth season. During the banding seasons 1960-1966, 21.7 per cent of the adult geese captured had been banded by us in previous seasons.

The snow geese arrive early at Anderson River, preceded only a few days by the white-fronts and whistling swans. They are paired, and apparently have already copulated when they arrive from their staging areas.

Their nesting islands in the middle delta are usually completely snow covered when they arrive, and the first geese congregate on the runoff channels, if they have formed, or on the wind-cleared mud flats opposite South Bluffs. In most years, the crucial hummocks, ridges and channel banks are cleared by May and nesting has begun by the end of May or the first of June when the peak of the snow goose migration passes through towards Banks Island. Some of these later arrivals are Anderson River Delta birds; they take up territories within four days and begin nesting as soon as physiologically possible. Our saying, "When the first snow goose egg is laid, within four days break-up bets will be paid" has been generally true every year of the study.

Because the snow geese are among the earliest nesters inhabiting the delta, the date of clearance of snow and melt water from their nesting habitat is most influential on their nesting success (Figure 60). As the habitat clears flocks break up into smaller groups, then pairs are seen spread out over the snow fields. Each pair is standing beside a bit of exposed bare ground. This may be the slightly raised ground of a former nest site or hummock; usually it is on a ridge or levee where strips

of bare patches retain the sun's heat and quickly connect into an open ground that becomes the dense centre of the colony. Size of the territories in the centre is controlled by the rate of snow thaw. If it is rapid, there is more space available for nesting during the 10-day nest initiation period, and territories are larger. If the thaw is slow and there is little bare ground available for nest sites, the territories are smaller, territorial fights are very frequent, and only the most aggressive geese are successful. Once the nest initiation period is over the whole area may clear, but no further nest attempts are made that season.

The nest-to-nest distances in dense areas in the central parts of the colony can be as little as 10 to 15 feet, but they may average about 50 feet apart along a ridge 100 to 200 feet wide; nests along such a ridge are most dense near a channel bank, thinning out on the side toward a mud flat or slough. On the outer fringes of the colony, territories are much larger and are loosely defended except for the core area of about 20 to 30 feet around a nest (Figures 44 and 45).

Territorial defense in a crowded snow goose colony is almost vicious. Before incubation, the fights are male vs. male, and female vs. female. If the threat display does not drive off the intruders, fighting begins: the opponents bite each other on the upper breast or on the side of the neck, at the same time hitting each other with the wrist of the wing. Territorial boundaries are ignored and the combatants become embroiled with other geese. Such fights can turn into a general mêlée in which as many as 14 geese have been involved. Usually territorial battles end after 10 to 30 seconds with threat displays at the boundary line, or a flying escort of the intruders out of the territory. Finally the resident pair run toward the nest; they face each other and perform a

Figure 44. Snow goose nesting habitat.
(Geese in communal area in background.)

Figure 45. Snow geese near nest of willows and grass.
Photo by Cy Hampson.

"mutual triumph display" (Cooch, 1953). In a crowded colony where little habitat has yet cleared, the atmosphere is clamorous with threat, fight and triumph calls. The stress of continual territorial fighting may contribute to the reduced clutch sizes recorded in late seasons, as discussed in the section, Incomplete Reproductive Cycles.

Ordinarily, snow geese make frequent use of common grounds, and they often wander far from their territories during egg laying. They rest in flocks on the snow or gather to feed in meadows that still may be covered with melt water. Some that had laid as many as four eggs were shot while feeding on overwintered cranberries and new sedges in the ptarmigan willows or while at the Wood Bay beaches after grit; this was during a season when the jaegers arrived particularly late and when foxes were scarce, so that the chances were slight that they could have lost their nests to predators. Such feeding flights help keep the geese in better condition for the long drain of incubation and molt.

Use of communal grounds during egg laying may permit the dense nesting one sometimes finds. The accidental timing of egg laying by two neighboring females may be such that each completes a clutch before either discovers their proximity to each other. If the eggs survive a few ensuing territorial fights, the neighbors finally learn to live close together.

In late seasons, when territories are at a premium, the geese are almost always on the territory or on a communal ground nearby. The physical drain on birds already hard-pressed by a late season is made greater by increased territorial defense and less time for feeding.

Nesting, Incubation and Hatch: Compared to the brant, the snow goose builds an elaborate nest. Sometimes they use a scrape or depression, but

a nest on higher ground built of the surrounding sparse grass and willow is more usual. In crowded colonies, the nest may be on a bare mud ridge and the grass and willow twigs are fetched to it from elsewhere. Tables VI and VII compare amounts of material used, and the nests' height above water and distance from nearest snow or melt water. Old nest depressions are re-used if they persist from the previous season, but ordinarily these have been washed away by fall storm tides or are silted up in the spring.

Selection of the site is made by the female who builds the nest around the eggs. The first egg, which may be laid in a scrape, is so cleverly covered that one-egg nests are hard to find. Very little material is added with the second egg, but with the third the nest really takes form. Snow geese use a sparse amount of down at this point, but it is not very cohesive and if much is used it is easily wind-strewn. The poor quality of snow goose down may account for the comparatively large nests which are built on drier sites than those of brant. As incubation progresses, the female snow goose also develops a brood patch.

Eggs are laid at the rate of one per day, with perhaps a skip of a day between the second and third and the fourth and fifth eggs, (Cooch, 1958). The average clutch is four to five eggs. Like most other arctic nesting birds there is no re-nesting if a completed clutch is destroyed, but a destroyed partial clutch may be completed in a new nest in the same territory. Birds trying to nest after the 10-day nest initiation period for the whole colony probably are still flightless at fall freeze-up and likely are eliminated from the population.

Table VI. Snow goose nest material and use of down.

(Percent of nests in which material is used)

	"Grass"*	Willow** leaves	Willow twigs	Old Nest
1959 23 nests	90.9	81.8	86.4	nil
1960 104 nests	88.5	57.7	46.2	4.8
1961 77 nests	92.2	31.2	16.9	44.2

* predominantly Elymus arenarius

** Salix arctica

Egg at which down is first supplied during laying (percent of nests)

No.	1	2	3	4	5	6
1959 19 nests	10.5	21.1	21.1	36.7	5.3	5.3
1960 104 nests	1.9	8.7	30.7	42.3	13.5	2.9
1961 62 nests	21.0	9.7	24.2	27.4	12.9	4.8

Table VII. Proximity of snow goose nests to snow and water.

Height in inches of nests above normal high tide line or standing water. (at start of nesting)

	1959 (23 nests)	1960 (104 nests)	1961 (77 nests)
Average	5.1	17.1	7.4
Lowest	1.0	1.0	0.0
Highest	24.0	30.0	18.0

Distance in feet of nests from snow cover

	1959 (23 nests)
Average	22.2
Closest	5.0
Furthest	75.0

Distance in feet of nests from standing water

	1959 (23 nests)
Average	19.2
Closest	1.0
Furthest	50.0

Gillham (1940) states that snow geese at Kendall Island made a second story nest over flooded-out eggs. This has happened at Anderson River Delta, but it did not represent re-nesting; the total of the eggs in all layers was equal at most to the average clutch size. In those nests where the bottom layer contained a complete clutch abandoned in the flooding, the nest on top was made by a different female, since, as explained by Cooch (1953) and Barry (1960), snow geese and brant are determinant layers.

The nests with exceptionally large numbers of eggs described by Gillham could be the result of flooding or of late seasons when cleared habitat is limited. Dump nests or random dumping of eggs is rare: it is physiologically uneconomical for a goose to dump eggs which dould be resorbed at a time when fat reserves are needed. Furthermore, it would seem territorial fighting would inhibit dumping in other nests. But dump nests do occur. The largest one found at Anderson River Delta had 16 eggs; the female had considerable difficulty incubating them, and the nest was eventually destroyed by jaegers. The eggs were probably contributed by at least four females. In 1957 at East Bay, Southampton Island, an early nesting pair of snow geese had four eggs which were usurped by a mixed pair, blue and snow geese, which added four more eggs. The mixed pair were ousted by a pair of blue geese, and four more eggs were laid. The 12 eggs of three females were incubated by the female blue. Eventually, the nest was destroyed by jaegers.

Incubation begins when the last egg is laid, the earlier eggs remaining dormant until the clutch is complete so that all hatch within 12 hours. Incubation time averages 22 days (Cooch, 1953). The female leaves the nest at least once a day, escorted by the male, to feed as

fast as she can and hurry back to the nest. The male is watchful for predators all the time she is gone.

Because snow geese nest before most other waterfowl and have a shorter incubation period, theirs are the first eggs to hatch, in late June and early July, when mosquitos on which the~~y~~ young feed heavily are thickest. Just before the eggs start pipping the parent birds become very protective of their nest and if approached will stand over it with wings outstretched, uttering growling threats. The more aggressive birds will attack human intruders.

Hatching success is usually high; few eggs are infertile or abandoned. The young (Figure 46) hatch and dry in 12 to 72 hours. If undisturbed before all are hatched the parents can call the entire brood from the nest at once. If molested, only the dry young are led away, and the wet ones are abandoned, to attach themselves to passing broods later if they are lucky.

As with brant, the male snow assumes protective care of the brood, but the female does the brooding. The young can dive within a day or two of hatching, but they are not as inclined to do so as other species of geese. In about a week the parents recognize their own young and the family groups tolerate closer contact with each other, each maitaining its mobile territory even under comparative stress, as when herded into a banding pen (Figure 47). Flocks of family groups are thus formed. The nesting grounds are soon abandoned and the geese move either to the inner or outer delta to favored feeding grounds. Eventually they move along the Wood Bay beaches to other creek and river mouths.

Since the 24-hour daylight lasts until the young are nearly full-fledged they can feed almost continually and their growth rate is

Figure 46. Snow goose female with dry young.
Photo by Cy Hampson.

Figure 47. Snow geese in mobile territories during time of stress.
Photo by J.C. Holmes.

rapid (Figure 48). In pintails, periods of inactivity in the continual daylight are much shorter in the Arctic than further south, and the time from hatching to flight is as much as four or five days shorter in the Arctic (Irving, 1960).

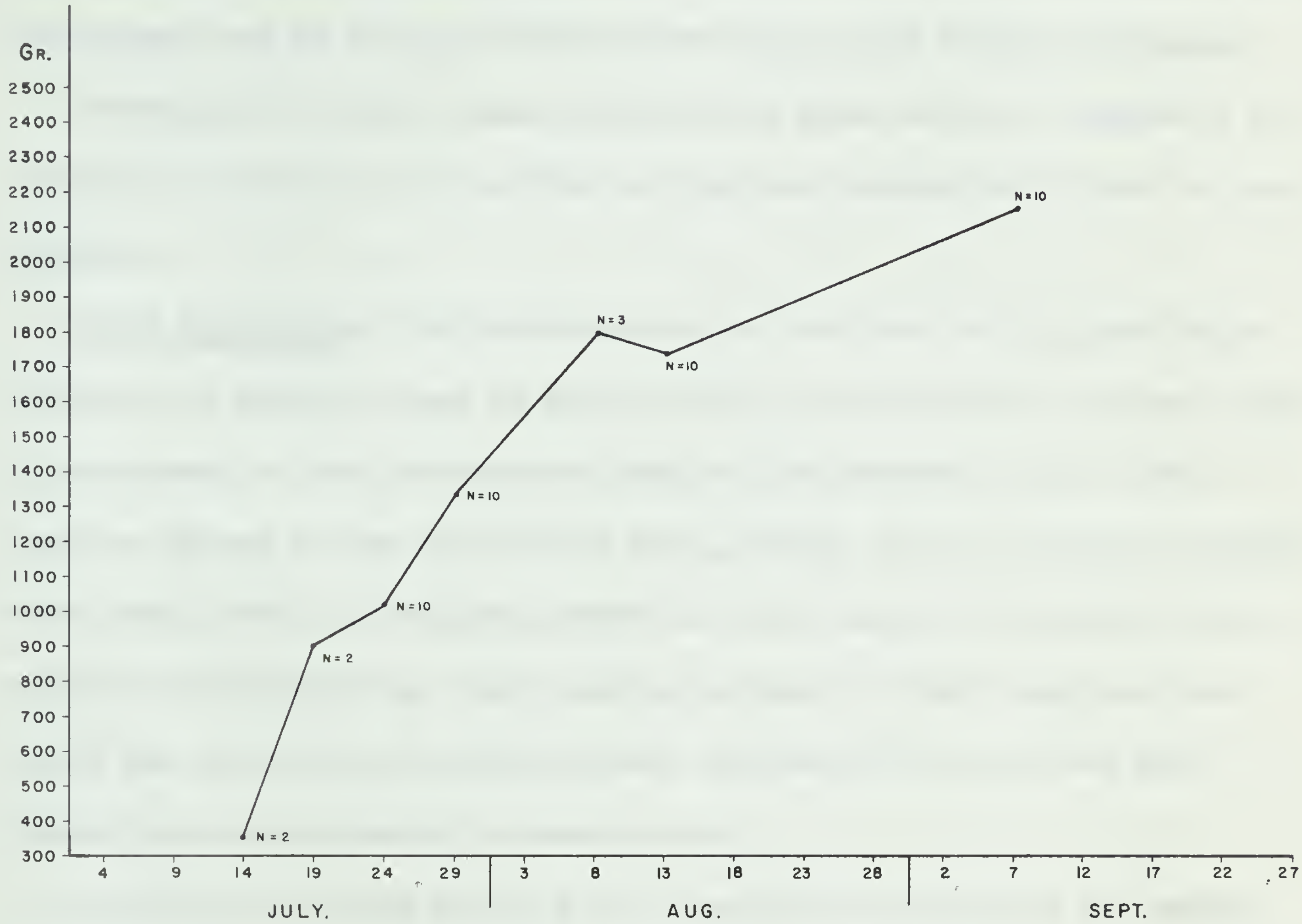


FIGURE 48, WEIGHTS OF YOUNG SNOW GEESE.

The rapid growth of young snow geese is all the more spectacular in view of the extremely heavy infestation of parasites during this period. Holmes (Appendix D, and personal communication, 1961) collected as many as 800 tape worms from three-week-old snow geese on Banks Island in 1961. Young snow geese taken in fall migration about 45 days later were comparatively parasite-free.

<u>Molt</u>: The annual molt of the non-breeding sub-adult snow geese is consistent from year to year, and is apparently controlled by day length. Their molt occurs in traditional areas on the periphery of the major breeding grounds beginning about July 1.

The date of the molt of the successful nesters occurs about 2-1/2 weeks after the young hatch and appears to be controlled by the timing of the reproductive cycle, which in turn is controlled by spring weather conditions on the nesting grounds. The molt lasts about 3-1/2 weeks so the parents are in flying condition about five days before the young.

Unsuccessful nesters molt earlier than other adults. Depending on the time of failure, this earlier molting can coincide with that of non-breeders.

Fall Migration: The non-breeders are the first to fly, and begin to leave the molting areas on Banks Island by the middle of August; they fly southwest to the northwestern edge of the Mackenzie Delta, where they are joined by the adults with young, which arrive in early September. Birds from Kendall Island have moved into the same area, mainly by molt migration dispersal from their nesting grounds. These large combined flocks may stay as late as mid-October (October 12, 1966, when they finally were driven south by heavy snow).

At first the geese build up their weight by feeding on the sedges, grasses and equisetum of the outer Mackenzie Delta. As these plants turn brown the flocks move inland to the rolling foothills of the Richardson and British Mountains to feed on cranberry, curlewberry, salmonberry or yellowberry (*Rubus chamaemorus*) and cotton grass tubers (*Eriophorum angustifolium*), etc. Many roost in flocks of about 200 to 1,000 birds on the small lakes and marshes among the hills. Others develop the daily food flights that become so ritualized later on in the prairies and on the wintering grounds. These birds stay on the flat islands of the outer Mackenzie Delta all night, making a sunrise flight into the hills to feed and loaf, returning to the flats at dusk.

Some flocks use the more northerly part of the delta and make feeding flights into the higher parts of Richards Island. This group has a high percentage of birds from the Anderson River which is virtually emptied of snow geese by August 20 in normal years. By then, the young are strong enough to make the 150-mile flight to the Mackenzie Delta.

Another concentration point on the Arctic Coast is Bathurst Peninsula between Baillie Islands and Harrowby Bay which is used in seasons of early freeze or snow on Banks Island. It is only about 125 miles across Amundson Gulf from the Banks Island breeding grounds. In some seasons, and perhaps every year, large numbers of snow geese gather in the rolling country west of the Smoking Hills from September 5 to 18.

The length of time the geese are allowed to spend in these staging areas affects their weight and physical condition for the fall migration. In 1966 when the spring nesting was early and fall freeze was late, young snows attained weights up to six pounds by the time they departed for the south in October. The time available is dependent partly on whether spring conditions permit early or late nesting and partly on the onset of fall snow cover. If the birds are forced south before they are ready, their flight to the next concentration point is a severe drain and they may be forced to interrupt their migration to rest along the islands of the Mackenzie River and in such feeding lakes as Brackett Lake near Normal Wells, 500 miles south.

The southward flight follows the Mackenzie Valley to the Athabasca Delta in northeastern Alberta or to Hay Lakes in northwestern Alberta. Recently, because of high water, the Hay Lakes concentration has shifted southeast to the Peace River country. Some, mostly non-breeders, push on to central Alberta and Saskatchewan. The main exodus from the Arctic Coast

occurs about September 15 to 20 but can be as late as October 12, as in 1966. The 1,200-mile flight to the next staging point is at fairly high altitude, 5,000 to 8,000 feet (according to radar and aircraft observations), and is non-stop for most of the snow geese. In 1960 I was in Hay Lakes when they arrived; my survey on September 17 revealed that among 25,000 white-fronted geese, 15,000 Canada geese and 200,000 ducks in the lakes and flats there were only five snow geese. On the misty rainy night of September 18 we heard the cries of arriving snows, and the next morning flocks of snow geese appeared from near the bases of cumulus clouds which our pilot estimated at 7,000 feet and did the "falling leaf" nearly straight down into the water. Within 45 hours the population of snow geese at this waterfowl resort increased to an estimated 160,000.

A bush pilot who happened to be flying down the Anderson River toward Nicholson Island under a low overcast September 18, 1960 flew into the start of a part of that migration, apparently from the Bathurst Peninsula staging area; he had to make frequent maneuvers to avoid the on-coming flocks.

The Indians of Hay Lakes are aware of the importance of the physical condition of the geese in determining the character of their migration in and out of their hunting grounds. In 1960, the first geese shot were very fat. The local hunters stopped all other chores and hurried to get in a supply of geese, saying that "when the wavies arrive fat, lots don't stay around for much more than a week." If the geese are thin on arrival at Hay Lakes, they linger until freeze-up, about October 10 to 15, to fatten up.

From northern Alberta the geese move onto the grain fields of the prairies of south central Alberta and Saskatchewan, about 500 miles away.

This appears to be the stage at which the family groups begin to break up, as brant do at Izembek Bay. There is nearly continuous movement through this area as the geese work their way south as far as Montana from late September to the end of October. The peak concentrations in the prairies are in mid-October. From the prairies they cross over the Rocky Mountains into Oregon and California. The build-up in northern California and Oregon continues through late October and November until the geese move onto their wintering grounds in the Sacramento Valley and south into west central Mexico.

WHITE-FRONTED GEESE

Anser albifrons is called by many local names: white-front, speckle-belly, laughing goose, yellowlegs, willow goose, tingmiak and brant, the last applied in the interior prairies where true brant are never found. All names except brant are equally descriptive. Among the Anderson River birds the "white front," that is the white patch behind the bill from which the name derives, is barely noticeable on account of the orange iron stain common to most waterfowl of the region.

For two seasons, 1961 and 1962, one or two partial albino white-fronts were seen among the Anderson River birds. A. Dzubin, Canadian Wildlife Service (personal communication, 1963), reports partial albinos in the fall flights in Saskatchewan.

Distribution: Figure 49 shows the distribution of recoveries of white-fronts banded at Anderson River and vicinity. They are birds of the Central Flyway, wintering along the Gulf of Mexico in coastal areas of western Louisiana, Texas and east central Mexico. Returns indicate that white-fronts remain in strong family groups longer than do other geese.

Spring Migration: White-fronts follow the Great Plains east of the Mississippi River northward to the Missouri where they trend to the northwest into west central Saskatchewan, and, to some extent into eastern Alberta. The plains offer almost unlimited feeding and resting places all the way, but there are some favorite concentration points along the route.

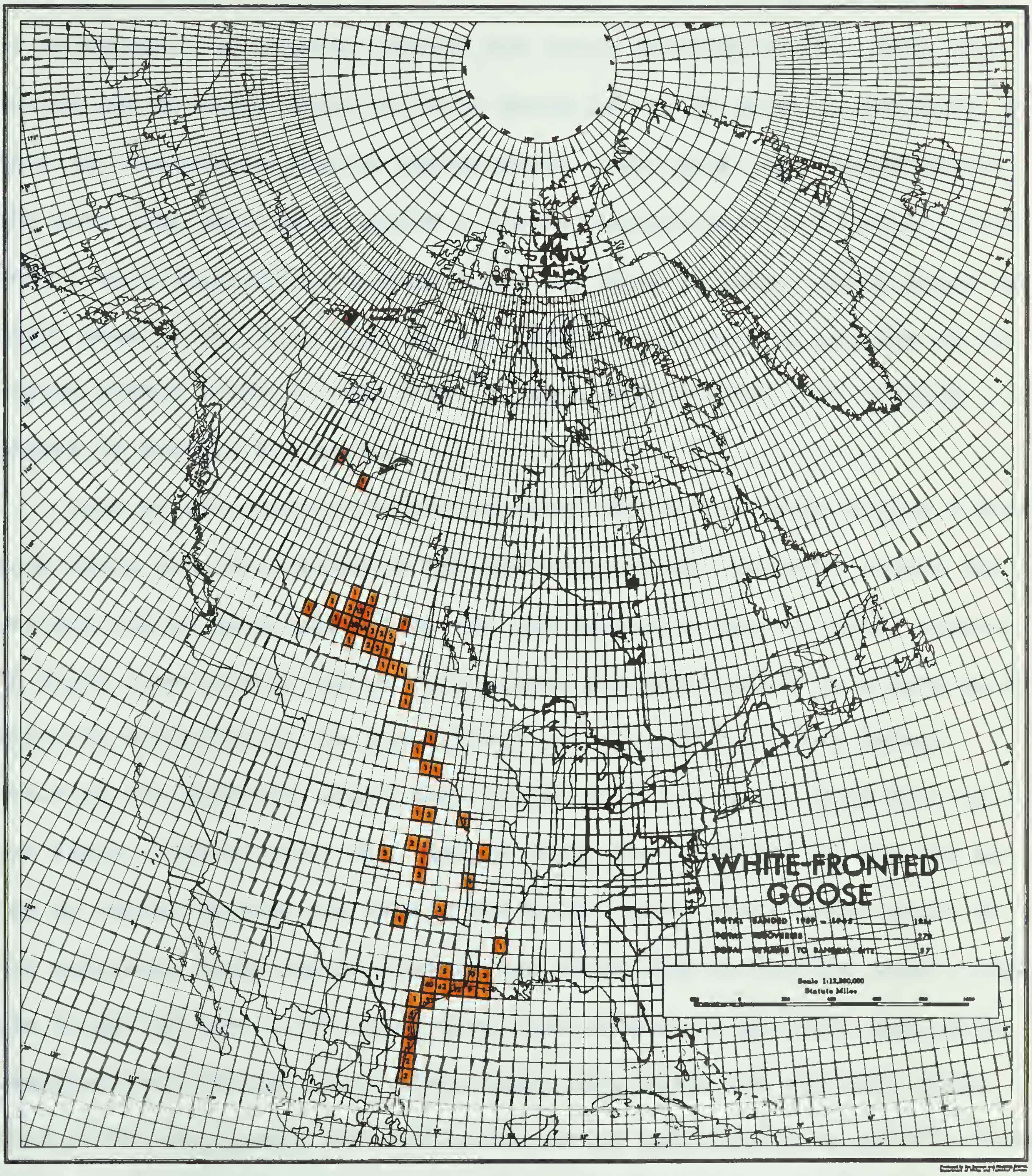


Figure 49. White-fronted goose distribution map.

The first of these is around Beaumont, Texas, which attracts large numbers of white-fronts in late February and early March as the flocks wintering in Mexico move back onto the Texas coastal plains. The next is in Nebraska where peak numbers are found about March 20. They then follow the Missouri basin to reach South Dakota by April 1, and move into the Kindersley area of Saskatchewan about April 20, approximately the same time snow geese arrive a little further west in Alberta. They remain near Kindersley, feeding among the wheat stubble, until about the first week in May when they fan out toward their nesting grounds on the willow tundra north of tree line, a range that extends from eastern Alaska to Boothia Peninsula.

Some of the Anderson River-Liverpool Bay white-fronts follow a northward route from Kindersley to the Athabasca River, stopping toward the western end of Great Slave Lake and the Mackenzie River. Still others, if field observations are an indication, probably travel in a more northwesterly direction to the Peace River country and Hay Lakes before reaching the Mackenzie where they gather at Mills Lake. Sand bars and mud flats, flooded snyes and sloughs along the river may be visited as far as Little Chicago and Arctic Red River before these birds cross to the Anderson, Smoke and Kugaluk rivers which they follow to the coast. But the flight of some 1,800 miles from Saskatchewan is probably made with comparatively few and short stop-overs; they leave the prairies after most of the snow geese have left, but arrive on the nesting grounds first.

The year-old white-fronts are still with the family group on arrival. This may also be true of the two-year-olds which appear to be among the main migrating flocks.

Nesting Distribution: White-fronted geese are not colony nesters. They spread out over the coastal plains to nest beside the thousands of lakes, tributary streams and rivers. The particular nesting population I designate as the Anderson River-Liverpool Bay segment is distinctly separated from others by considerable stretches of apparently unsuitable habitat. This population seems to be bounded on the west by a north-south line through the fingers of Eskimo Lakes, and on the south by the tree line at Kugaluk and Miner River junction and Husky Bend in the Anderson River, to the east branch of the Mason River, then north to Harrowby Bay. It includes a few birds nesting in the Horton River, as well as those of Tuktoyaktuk Peninsula south of Cape Dalhousie and the bays and inlets of the Beaufort Sea coast west to Hutchinson Bay (Figure 1).

The combined breeding and non-breeding population of this area is approximately 25,000 birds, making the white-front the most abundant goose in the Anderson River-Liverpool Bay country.

White-fronts are so widely scattered and so secretive that nests in the more inland sections are very hard to find. However, there are places where they tend to concentrate: the Kugaluk and Miner River junction, the flats formed by the Moose and Smoke River deltas on Liverpool Bay, the bottom of McKinley Bay on the north coast of Tuktoyaktuk Peninsula, the inner delta of the Anderson River, Mason River's inner delta, and to some extent the old bed of the Horton River at the east end of Harrowby Bay. During what might be called a molt migration, the parent birds bring their young to these places when they are about one week old, joining the molting non-breeders already present, but not necessarily mixing with them.

Yearlings stay with the family group through most of the nesting season, moving off somewhat only when they begin their molt just before the hatch, a behavior similar to the non-colonial Canada goose (Elder and Elder, 1949). Often these yearlings remain near their families throughout their molt instead of flocking with the older non-breeders in the vicinity. These yearlings, which we have dubbed the "yea chorus" for the on-cue racket they make if the family group is disturbed, serve as important protection for a pair of nesting adults by distracting and leading off intruders with noisy calls and short devious flights.

Of white-fronts banded as downy young and recaptured in successive years, 56.6 per cent were caught as one-year-olds and 44.4 per cent as two-year-olds. No third season birds were recaptured, suggesting to me that when they reach adulthood they leave their natal area to seek their own nest sites elsewhere in the Anderson River-Liverpool Bay country.

Reproduction: White-fronts first breed at three years of age, but there are indications that some breed at two years in particularly good seasons. The observation by Hansen, Scott and Queneau (1956) of an apparently adult white-front paired with a yearling, as well as similar observations of my own at Anderson River, are perplexing. In one pair collected the "adult" was a male, probably a two-year-old, with extensive belly speckling, while his mate was a yearling. It may be that this female would have nested when two years old and its mate three; otherwise, this would seem to be an evolutionary waste of one reproductive season for one of the pair. Also, these occasions of mating out of age class could be the result of one of a pair being killed during the spring migration. The sex ratio in all geese is assumed to be 50:50, and I am also assuming that both male and female mature at the same age, although this may not necessarily be the case.

White-fronts arrive in the delta early, as exploratory pairs. They do not settle down in large waiting flocks, but frequent the upriver sloughs and stretches of open water, where copulation may take place, and from which pairs and family groups wander back and forth. This is their final staging area, close as it may be to their nesting grounds.

I doubt they return to traditional nest sites because of the variation in snow depth, etc., from year to year. Furthermore, of the adult white-fronts captured in the 1960-1966 banding operations, only 5.7 per cent had been banded by us in previous years. Some probably nest in the general vicinity of a previous nest, depending on where the snow clears first. They may have a considerable waiting period for snow to clear because of the entrapment and drifting caused by willows and uneven terrain.

The territory, such as it is, is ill-defined for these solitary nesters. I have seen nothing resembling a territorial fight among white-fronts; at most a male or pair will fly escort to another pair as they pass near the nest site. Most of the territorial defense against intruders appears to be by the young of the previous year. They fly out to meet any predator or intruder, setting up a noisy commotion, and maneuvering the unwanted visitor away with tantalizing struts in full view, alternated with short flights and circlings. Sometimes an adult bird, probably the male, is with them. This behavior, used many times on our Chesapeak retriever, a specialist at catching white-fronts, always lured her away from the nest.

Nesting, Incubation and Hatch: The site is chosen by the female, she builds the nest around the eggs as they are laid. A shallow depression is used rather than a scrape. Material from within a few

feet of the nest is used sparingly. Down is also used in small amounts, and the female has a rather irregular brood patch (Figure 50).

Figure 50. Female white-fronted goose on nest.
Photo by Cy Hampson.

The egg-laying period of white-fronts appears to coincide with that of snow geese. There is about a 10-day period for nest initiation. Eggs are laid daily, with "skip days." No re-nesting is known to occur but replacement nests are made to complete partial clutches which have been destroyed. The clutch size is five to seven eggs, averaging larger than for other geese, which may be related to sacrifice of one or more young to a predator while the rest disperse.

The young hatch after 23 days of incubation, and are dry and ready to leave within about 24 hours. They are led to the nearest water, usually a small slough thickly edged with sedges. Observation of family groups showed that the male is most watchful of the brood, while the

female seeks to rebuild the weight loss from incubation. The brood is kept secluded for about a week, after which the family begins moving toward the river and lakes of the inner delta where they begin an almost continual movement or exploration. It is at this time that the families suffer the heaviest brood loss as the young easily become separated and lost in the dense willows and sedges.

White-front families tend to spread out or wander more than those of other geese. If disturbed suddenly the group breaks up at once, and individuals scatter. On the water, both adults and young dive well, and in a short while they can become widely separated. If driven ashore, some run with amazing agility through the willows, others hide at once, and still others sneak back into the water. Later on, when white-fronts are in flocks of family groups or molting non-breeders, they exhibit the same independence and disperse as individuals; in view of this behavior, it is surprising that the white-front family lasts longer as a unit than snow and brant families.

Young white-fronts develop rapidly, paralleling the growth of young snow geese; they hatch about the same time as snows and are able to fly at the same age.

Flocks of family groups form, break up and re-form from the time the broods reach the inner delta. Until the young are flying, such flocks seem to be transitory associations formed by chance meeting as the families roam. Eventually these flocks become more established and probably remain fairly stable through the fall migration when the geese become more gregarious.

<u>Molt</u>: The molt of breeding white-fronts, especially that of the female, is controlled by reproductive activity in the same way as the

molt of breeding snows and brant. The molt of sub-adults is controlled by annual rhythms; most of them, including the "yea chorus," leave the families at a time when the adult nesters are in late stages of incubation or, in early seasons, just as the hatch begins. They gather in flocks of up to 1,500 birds on traditionally used lakes, such as White-front Lake and Bipsi Lake, and channels for the molt, which begins about June 25 regardless of weather conditions. The largest flocks of non-breeders form at the Smoke-Moose river flats where nearly 20,000, with about an equal number of Canada geese, were seen in 1965.

Fall Migration: The white-front is said to be the earliest of the geese to migrate. Flocks have been seen in their favorite haunts in Saskatchewan as early as August 27 (A. Dzubin, Canadian Wildlife Service, personal communication, 1963). They do not necessarily start south before the other geese, but do not resort to large staging areas in the north, rather, they seem to move more directly south and to become strung out along the migration route.

Non-breeding white-fronts regain flight by August 1. They are strong on the wing and fly around the inner delta in noisy flocks. Darkness falls at midnight about this time, and coincidentally the flocks tend to move further upriver to sandbars, and willow and sedge-lined sloughs. By August 15 to 20 they are gone and their laughing night calls are no longer heard.

Young and adults may begin flying as early as August 10, and it is possible that some are able to start south with the non-breeders. By August 20 in normal seasons all of the young can fly. By this date, sunset is about 9:30 p.m. and evening flights of family group flocks are a common sight. By August 25 these flocks also have scattered, some

heading south and others dispersing across the coastal plains as far as the Mackenzie Delta. The departure south is a continual process; in 1966 the last white-fronts were seen on October 7, when a considerable flight, apparently from the north Alaska coast, turned into the Mackenzie Delta and headed up the valley. This flight preceeded the final snow goose exodus and first winter snowfall on the coast by only three days.

There are no main concentration areas in the flight up the Mackenzie. Again, islands, snyes and side sloughs are often used as are the river banks and sandbars exposed by low water. In the two fall seasons I spent at Brackett Lake near Norman Wells, a considerable number of white-fronts came and went in a daily procession until September 20. (In 1959 the lake froze September 22.) They also may gather briefly at Mink and Mills lakes near Fort Providence. At Buffalo Lake in the northwest corner of Wood Buffalo Park, and at Athabasca Delta and Hay Lakes there were white-fronts by the thousands on October 5, 1962, a date on which some of the first migrants had already reached the Gulf Coast of Texas. The one big staging area for white-fronts of the Central Flyway is around Kindersley, Saskatchewan, where their numbers reach a peak in late September. If the weather remains good they may stay through nearly all of October.

From Kindersley, the flight south follows nearly the same route as the northward migration, except that few geese stop until they reach the Gulf Coast off Louisiana and Texas. In seasons of poor weather conditions on the nesting grounds or of early fall storms, the young may tire more rapidly, and frequent stops en route are made.

By late November the flocks have reached the Gulf Coast, and by December about half the population has moved on to winter in interior Mexico.

Physiological Changes Through the Reproductive Season

During the early stages of spring migration in late March and early April, I collected specimens of brant, snow geese and white-fronted geese in northern California and again at various stopping points on their way north, including Vancouver, British Columbia (brant), and Edmonton, Alberta, and points along the Mackenzie River (snow geese). Further collections were made at Anderson River Delta.

In spite of the 3,000 or more miles of spring migration, all three species of geese showed surprising weight gains; they are at their heaviest weight of the reproductive season on arrival at the nesting grounds. Hanson (1962) has shown this with Canada geese also. Figure 51 shows weight changes during spring, summer and fall, with the various reproductive events as they occur in an "average" season. Unfortunately, I had difficulty in obtaining an adequate number of specimens, particularly of white-fronts. However, similar trends are apparent in all three species.

Spring migrants are eagerly sought by native residents of the north, not only for cultural reasons but also for a change of diet. A taste of goose in May or early June is part of the rites of spring after a long winter. There is no doubt that spring geese are in better condition and are better eating than at any other time of year. Fat nearly a half inch thick encases the belly, and there are heavy fat layers around the gizzard, pelvic regions and folds of the intestine. All other species of birds collected on arrival at Anderson River also have thick layers of fat; this is particularly noticeable in the shore birds and waterfowl.

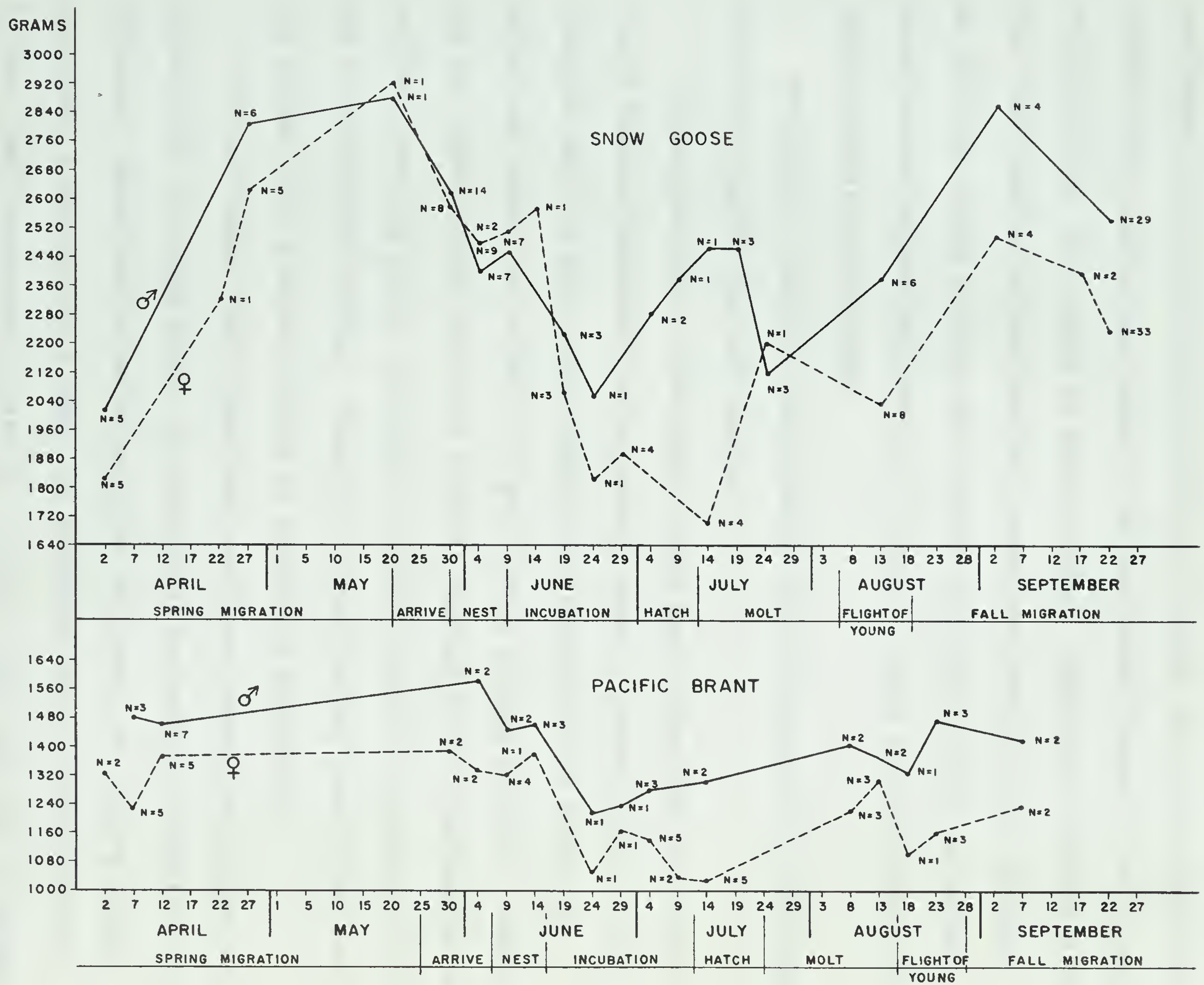


FIGURE 51, SNOW GOOSE AND PACIFIC BRANT BODY WEIGHTS

This fat reserve undoubtedly serves at least two purposes, and for the female, perhaps three. The nesting and feeding grounds are bleak and largely snow-covered upon the birds' arrival, and even in the best seasons, food sources are scarce. The fat serves primarily as an energy reserve during this period of food scarcity. Specimens collected during the first week or so after arrival seldom have food in their stomachs. As the land clears of snow, food habits of the geese shift as various plant species become available and they are finally able to feed on the nesting territory or nearby.

Secondarily, the fat, particularly the subcutaneous fat, gives added insulation against the cold weather.

The females, which often begin laying eggs before any appreciable food supply becomes available, are apparently able to convert much of their fat reserves into the yolk of the rapidly developing ovarian follicles. During egg laying the weight of a goose takes a sharp decline. Much of the fat reserves have been used up while waiting for the nesting habitat to clear, but egg laying represents a further drain, in production of eggs and in territorial defense. There is a slight weight gain at the end of egg laying, then a steady decline as incubation progresses.

For the female, this weight loss continues through the incubation period until the young hatch, at which point her weight is the lowest of the year. Mainly due to maintaining the territory, the male's weight continues to decline until about the middle of the incubation period. By this time, territorial strife is virtually ended and food is abundant. The male thengains in weight until the hatch, when his weight becomes static or may even decline as he takes over care and defense of the young. After the hatch, the female regains weight rapidly. She broods

the young periodically, but spends most of her time feeding with the young while the male watches.

About two weeks after the hatch, the annual molt of the parent birds begins, lasting for about four weeks, during which time all flight feathers are replaced. This very rapid growth of new feathers is reflected in another weight loss. After the molt, there is again a gradual increase in weight until the fall migration.

Figure 52 shows the rapid increase and subsequent drop in ovarian weight during the reproductive season. Note the short span of the egg-laying period. If the female is not able to nest during this period, the ovarian follicles become atretic and the yolk is rapidly resorbed. The weight of the ovary in birds with atretic follicles declines almost as rapidly as in those which have laid eggs (Barry, 1960).

In the males, the testes show a gradual increase in activity, beginning at the time of departure from the wintering grounds and reaching a peak on arrival at the nesting grounds, but declining rapidly after that. These changes are shown in testis weight (Figure 53), and in the quantity of sudan stained lipids which Marshall and Coombs (1957) found to have an inverse relation to testicular development and germinal activity (Figure 54). Note that appreciable numbers of spermatazoa do not occur until May, and that there is a sharp decline after arrival on the nesting grounds when the testis regresses in the early incubation period to near the winter level (Figure 55).

All three species of geese show similar patterns of adrenal weight changes (Figure 56). The one point of divergence between the sexes is the low adrenal weight of the female about midway in incubation, while that of the male reaches a high at that time. Low points for both sexes are just after spring migration, during the breeding period, at the start

of the annual molt, and again during the approximate mid-point of fall migration when the birds reach Alberta, etc. High adrenal weights are indicative of stress. Mallards and pintails also exhibit adrenal weight cycles with an increase leading up to the breeding season (Höhn, Sarkar and Dzubin, 1965; Phillips and vanTienhoven, 1962).

Also, both sexes of all three species of geese show similar patterns of thyroid weight change timed to the various events of the reproductive season (Figure 57). Thyroid sections were examined to study changes in activity, but changes in cell height were so slight that I conclude there was a rather steady production of thyroid hormone that was stored in the follicles until needed. Changes in thyroid weight then are taken to indicate a need for more thyroid hormone or an increased metabolic rate. Thyroid weights hit a low point upon arrival on the nesting grounds after the spring migration. There is a rise in thyroid weight just before egg laying, then a decline during egg laying and incubation. At the end of incubation and during the hatch thyroid weights rise sharply again, especially in the female. There is a slight decline just before the beginning of the molt which may be associated with the molt, but not necessarily a cause of it (Höhn, 1949). By the end of the molt thyroid weights reach a peak, and then decline during fall migration.

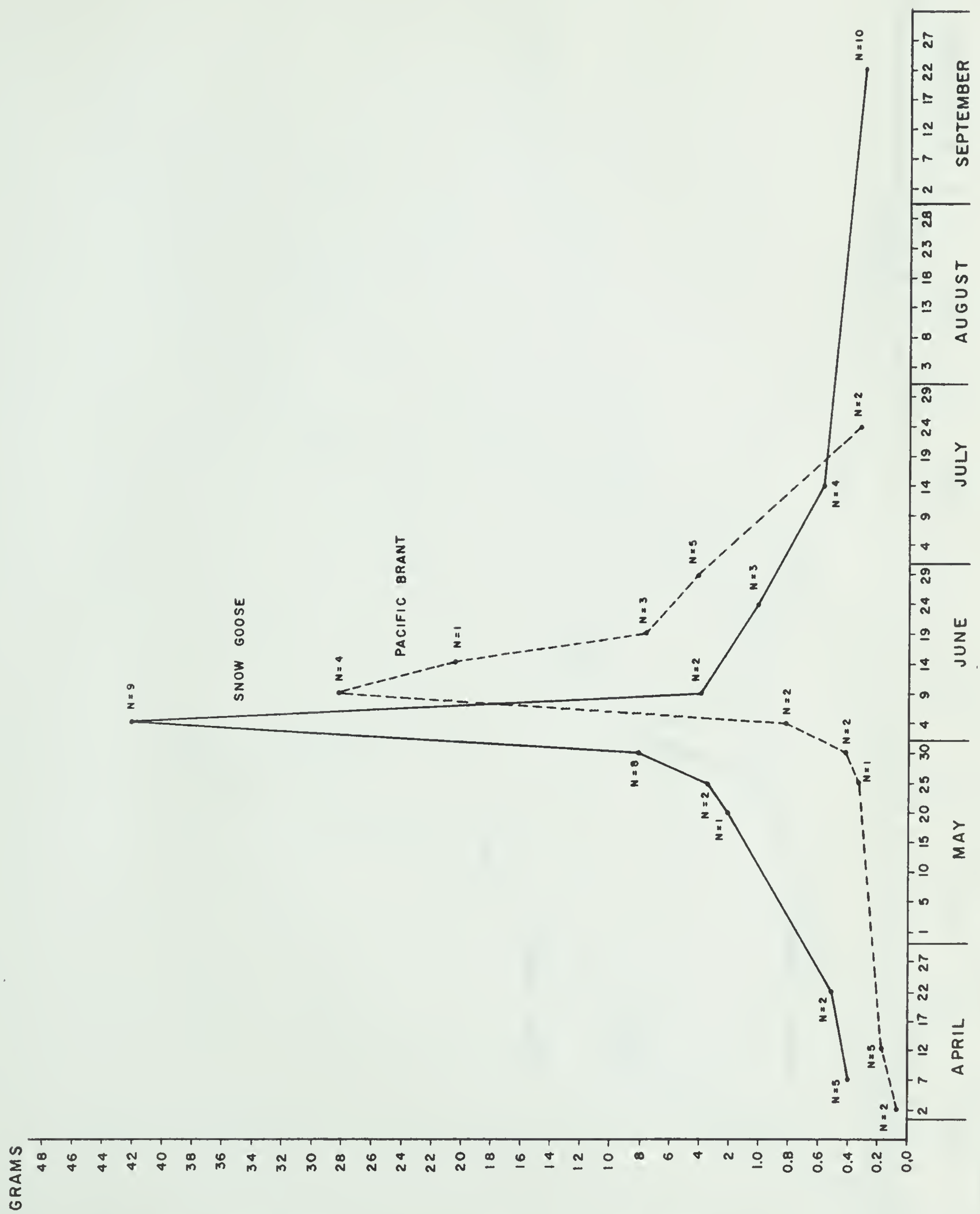


Figure 52. Snow goose and brant ovary weights.

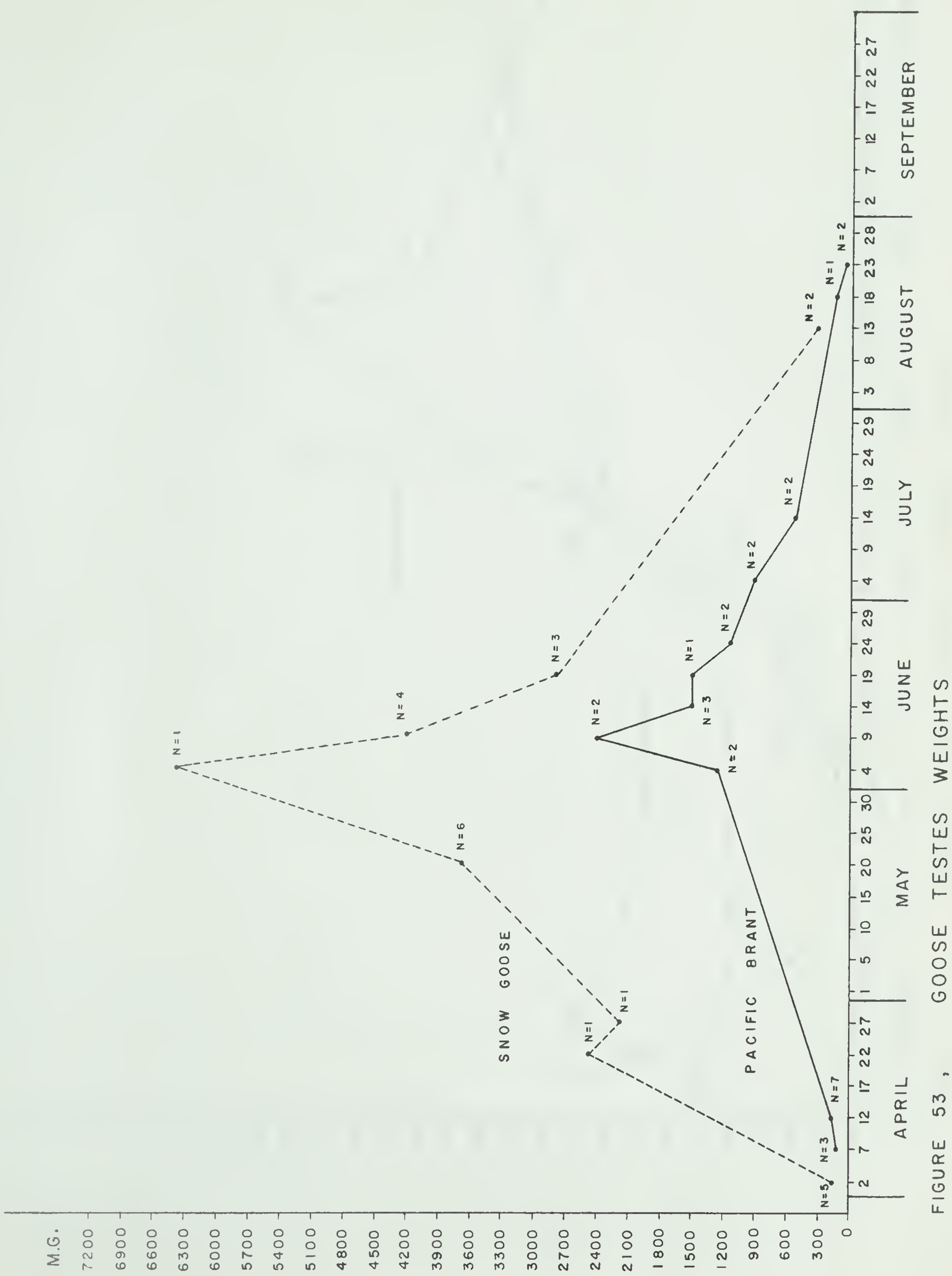


Figure 53. Goose testes weights.

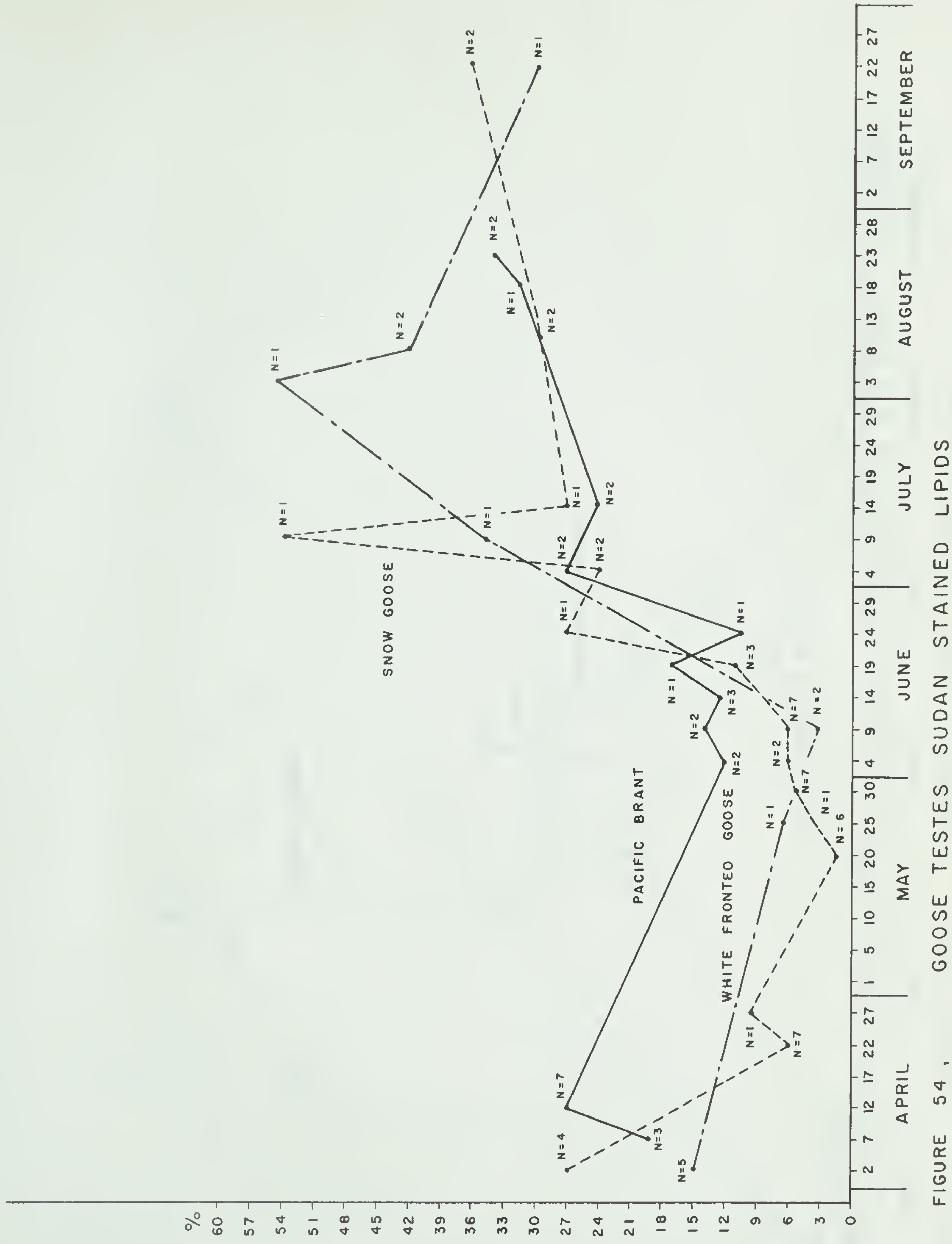


Figure 54. Goose testes, sudan stained lipids.

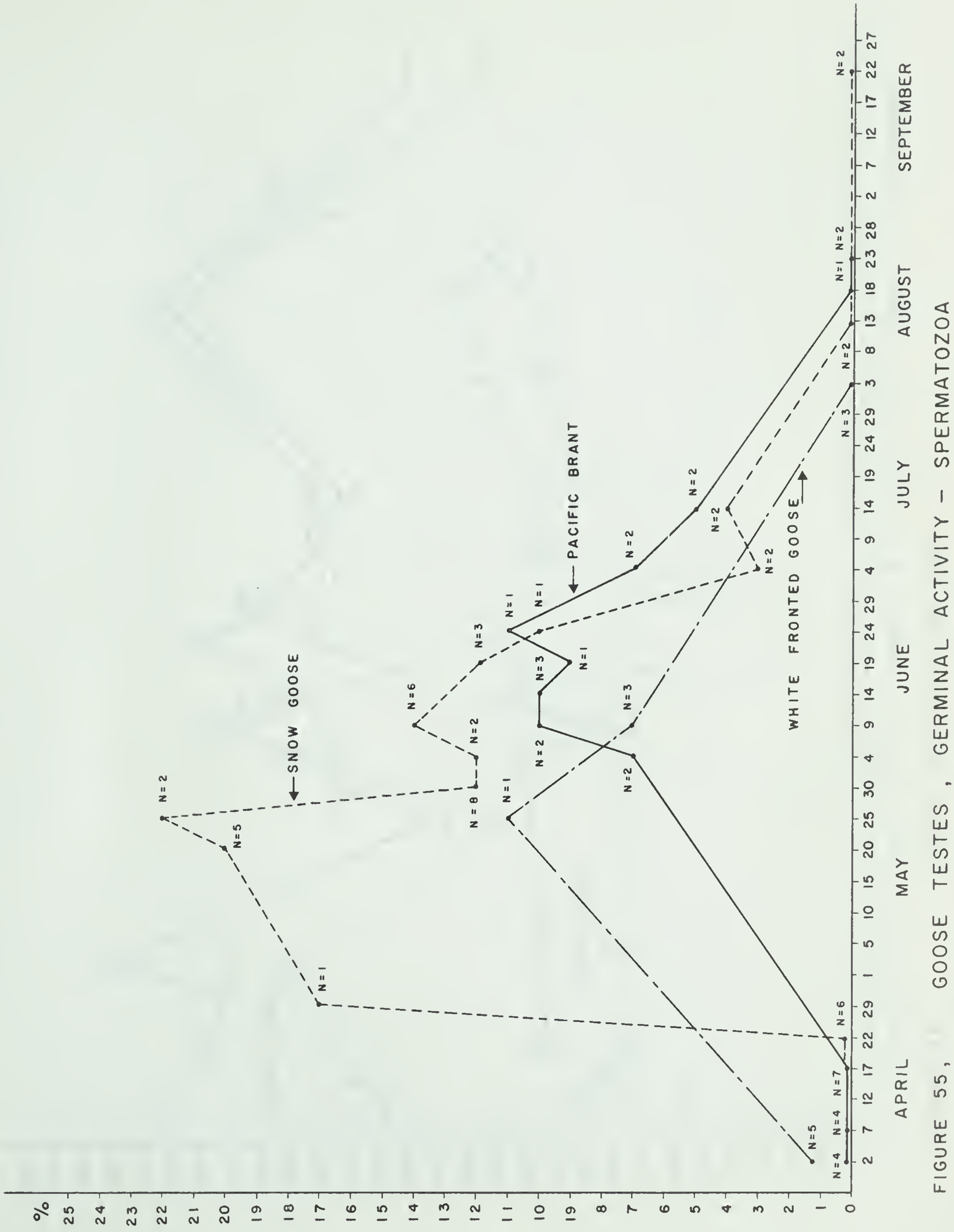


Figure 55. Goose testes, germinal activity.

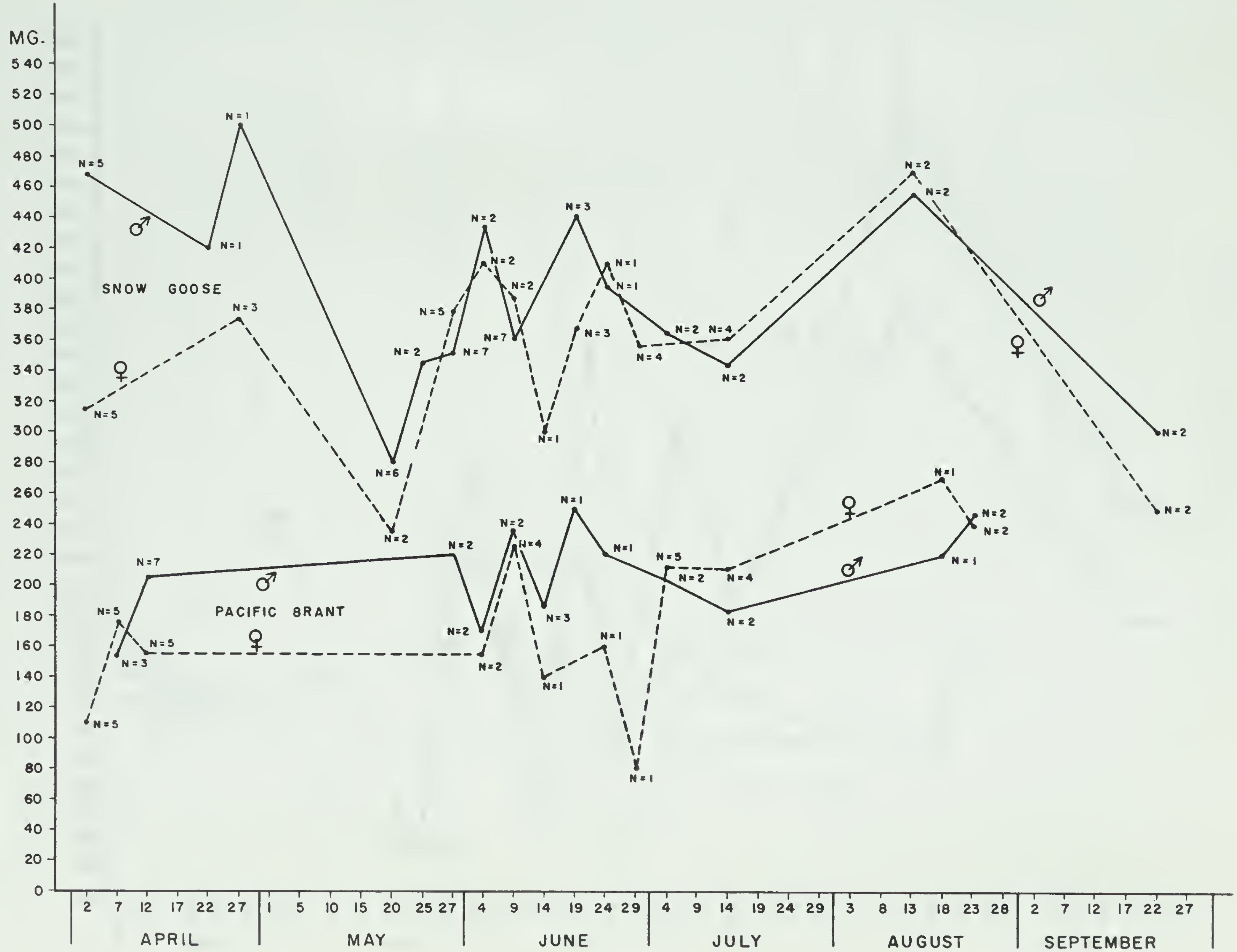


FIGURE 56, GOOSE ADRENAL WEIGHTS

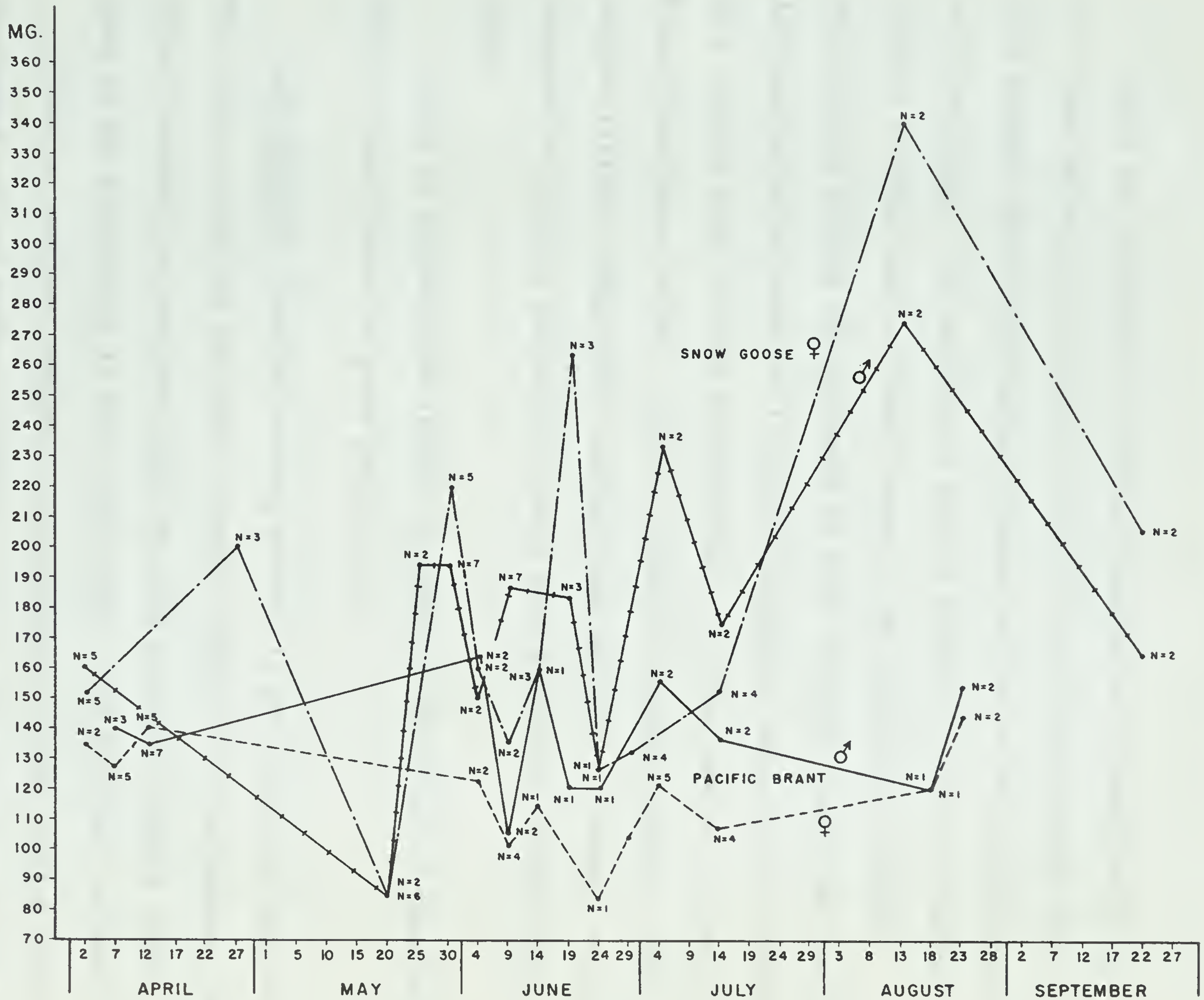


FIGURE 57, GOOSE THYROID WEIGHTS

Incomplete Reproductive Cycles

Since the institution of winter inventories of waterfowl by the U.S. Fish and Wildlife Service in 1947 it has become apparent that in some seasons various populations of geese arrive on the wintering grounds with few young. The unpublished work of Lynch does much to show the effects of these poor or "bust" years on the population of geese. Reproductive failure can be caused by many different agents and can affect isolated pairs of geese, or it can be widespread, affecting all the birds of a certain area, or even a population, as in the case of the Pacific Flyway snow geese in 1965. Early literature ascribes extensive reproductive failures among arctic nesting birds entirely to storms, but poor reproductive seasons can occur in years during which no violent storms occur.

Causes of reproductive failure in geese are discussed in descending order of their impact on goose populations.

Late Seasons: When the nesting habitat is not cleared of snow and melt water in time for the geese to nest, ovarian follicles become atretic and are resorbed so that fewer eggs are laid (note the reduced clutch sizes on the study areas in the "late" years, 1959 and 1964, in Table VIII.

Given the constant snow depth characteristic of the nesting flats, temperature and the amount of bright sunlight are the important factors in preparing the habitat for nesting. Figure 58 shows temperature records and Figure 59 the comparative temperature-sun index, for selected seasons of the study. These may be compared with Figure 60, showing the rate ~~and~~

and date of snow and melt water clearance from the habitat, and with the average clutch sizes in Table VIII.

Geese migrating to the arctic arrive in peak physical condition and have already copulated before the birds arrive on the nesting grounds. A female Atlantic brant I collected within three hours of the first arrival of brant on the nesting grounds at Southampton Island had sperm in the oviduct (Barry, 1962). Portenko (1937) notes that snow geese on Wrangel Island are ready to nest as soon as they arrive in the spring. Williamson, Thompson and Hines (1966) and Irving (1960) record that many other arctic birds, including passerines, arrive already paired, and are able to nest "immediately or after only a brief period."

Copulation, which presumably takes place at the last spring staging area, is probably controlled to a certain extent by the weather. Once the female has been inseminated and starts becoming physiologically ready to nest there may be only a certain length of time she can wait out adverse conditions before she must either nest or resorb her ovarian follicles. Local weather conditions at the last staging area may explain why some atretic follicles occur in "average" and "early" seasons on the nesting grounds (Table IX).

Resorption may be due to a complex of factors. The stress of the continual territorial fighting associated with reduced nesting habitat may be involved. In addition, less time is spent feeding during "late" seasons, and food is less available, so that the female probably has to draw upon her fat reserves to the utmost to maintain herself. Hosoda et al (1955) found that starvation in chickens decreases the production of gonadotropic hormone by the pituitary gland, and that this induces atresia.

That they are ready to nest on arrival is a great time-saver for the geese, but it is also a gamble that the nesting grounds are in suitable condition for nesting, i.e., clear of snow and flood water. The geese are adapted or synchronized to an "average" season, but since the average is not always the case they are able to wait for the thaw for up to two weeks.

Beyond that, the longer the thaw, or in other words the later the season, the harder the birds are pressed for food and warmth. After a certain amount of frustrating waiting they begin to resorb their eggs. The continual drain shows its effect. The drive for self-preservation takes over from the urge to reproduce. Uspenskii (1965) and Barry (1962) have both noted that arctic geese resorb their ovarian follicles during late or adverse seasons. The longer such conditions persist, the more ripening ovarian follicles become atretic and are resorbed; thus fewer than average eggs are laid. It is an observed fact that the later or more adverse a particular season is, the fewer young are produced in that season.

Table VIII shows the clutch size average and predation rate for all seasons relative to the date the snow clears from the nesting habitat. Figures 61 and 62 show the spectacular differences in snow cover from one nesting season to the next. Both pictures were taken on June 10, one in 1959 and the other in 1963.

From an evolutionary standpoint, birds trying to nest too late would probably still be flightless at fall freeze-up, and would probably be eliminated from the population.

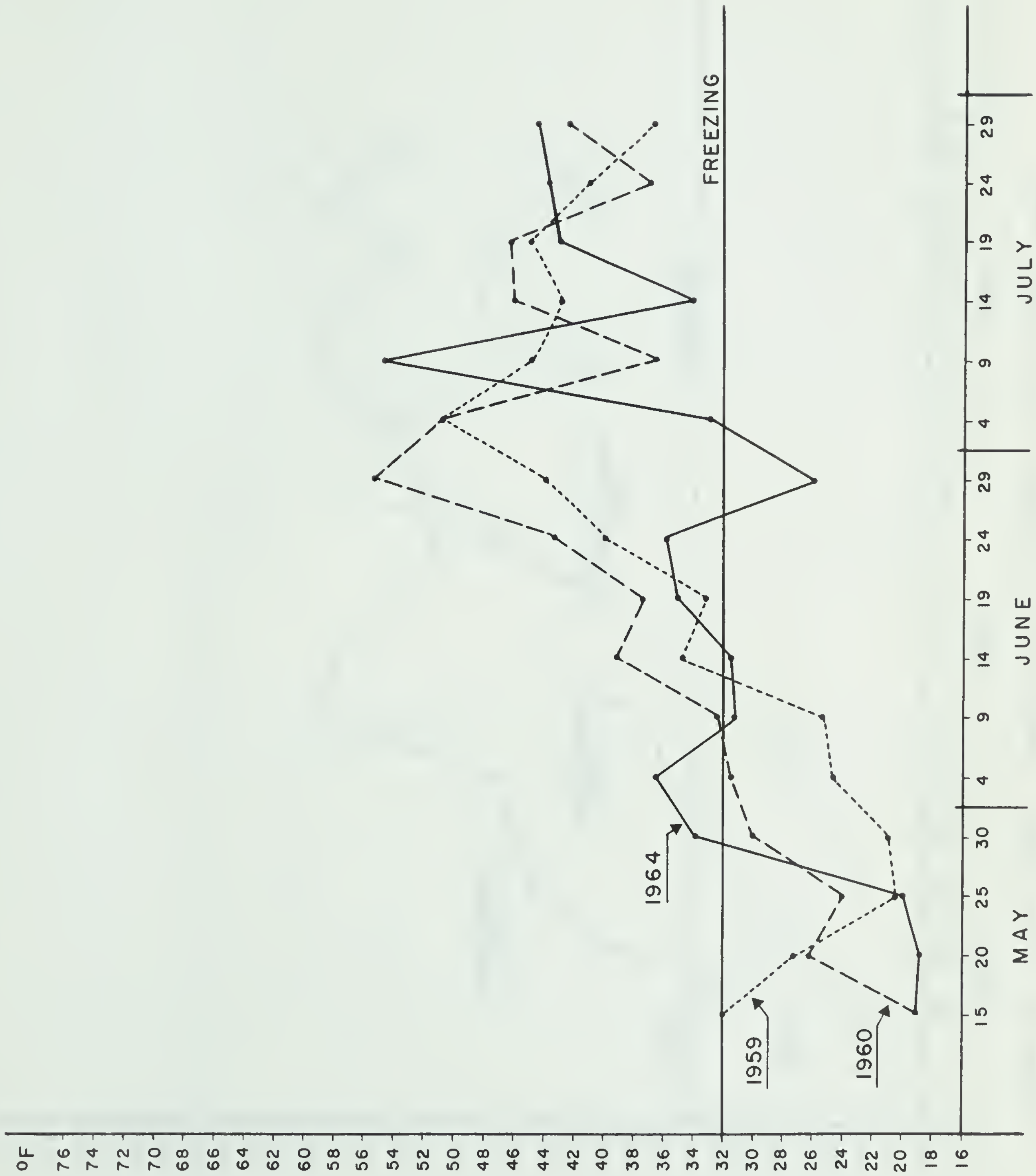


FIGURE 58: TEMPERATURE RECORDS: 1959, 1960, 1964
(5 DAY AVERAGE OF DAILY MEAN)

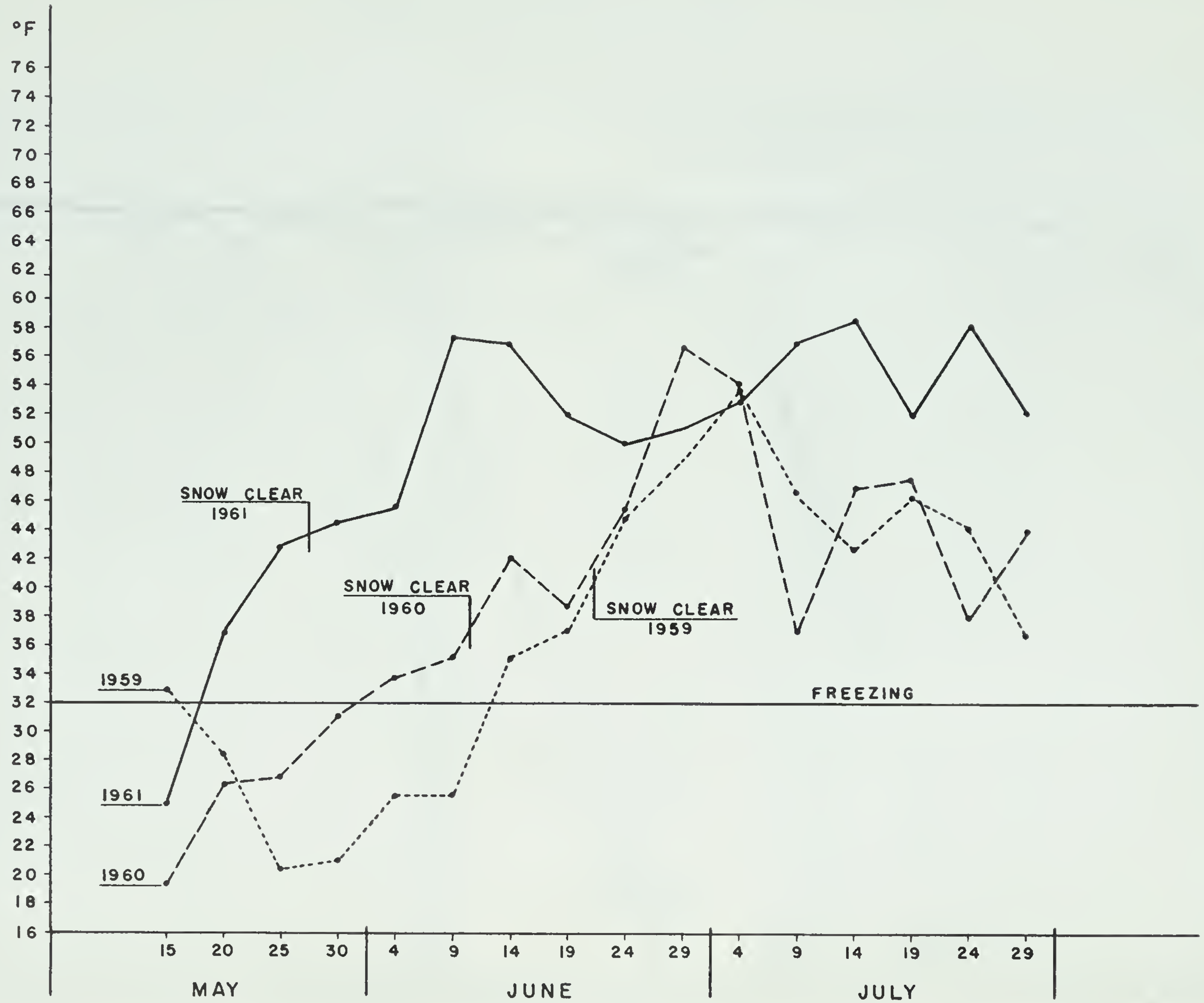


FIGURE 59: SUN-INDEX TEMPERATURE RECORDS: 1959, 1960, 1961
5 DAY AVERAGE OF DAILY MEAN
(ADJUSTED 0° TO 5° DEPENDING ON AMOUNT OF BRIGHT SUNSHINE)

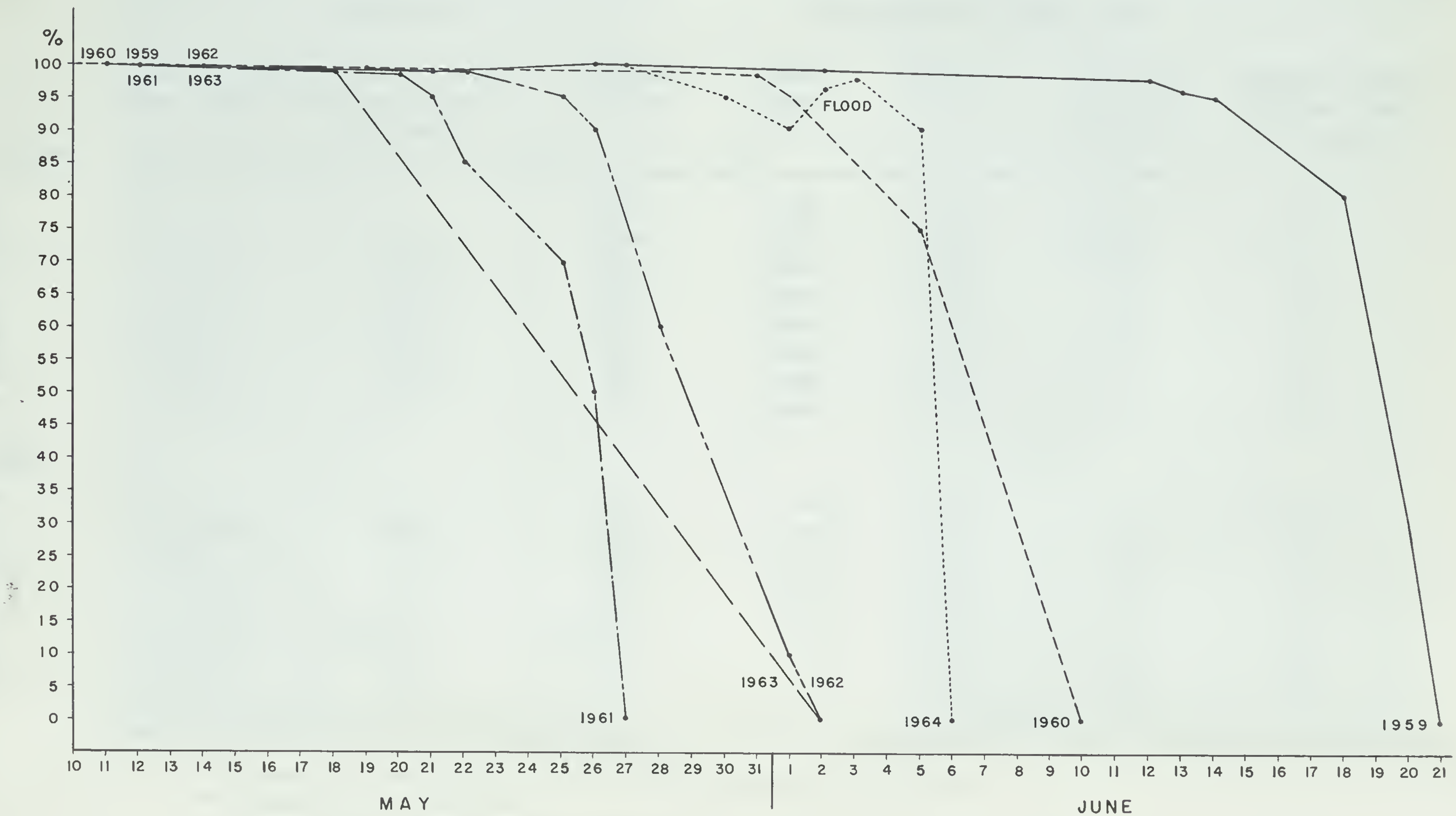


FIGURE 60, PERCENT OF SNOW COVER ON STUDY AREA.

Table VIII. Clutch size and rate of egg and nest loss

Anderson River Delta, N.W.T.

	Study Area		Nests Outside Study Area				
	Date of 95% Snow Cover	Average Clutch Before Losses 100 Nests	Number of Nests	Total Eggs	Average Clutch	Apparent Egg Loss (Percent)	Apparent Loss Complete Nest (Percent)
Pacific Brant:							
1958	-	-	325	946	2.91	*6.4	*5.5
1959	June 14	2.60	418	1065	2.54	**33.9	**71.1
1960	June 1	4.20	488	1971	4.03	3.0	6.6
1961	May 21	4.51	432	1398	3.23	5.0	21.9
1962	May 25	4.35	475	1912	4.02	1.3	2.5
1963	May 18	4.43	452	1648	3.64	*1.9	*4.2
1964	June 4	3.12	144	404	2.80	4.0	13.8
1965	May 28	4.25	574	1878	3.27	1.7	10.3
Snow Geese:							
1958	-	-	213	739	3.46	-	*12.2
1959	June 14	3.20	192	641	3.33	6.8	30.7
1960	June 1	3.95	498	1853	3.72	1.3	1.4
1961	May 21	4.56	800	2945	3.68	2.1	4.1
1962	May 25	4.32	581	2309	3.97	.1	.1
1963	May 18	***3.70	***1064	3761	3.53	*3.5	*4.1
1964	June 4	3.90	15	51	3.40	3.9	26.6
1965	May 28	4.33	566	2115	3.73	1.6	11.3

* Does not include loss to grizzly bear later in season.

** Primarily arctic fox.

*** Snow storm caused abandonment of nests; two nests may equal clutch of one bird.

Figure 61. Snow cover, June 10, 1959.

Figure 62. Snow cover, June 10, 1963.

Table IX. Follicular development in female snow geese.

1959 --- Late Season

Date Specimen Collected	Number of Ruptured Follicles	Number of Atretic Follicles	Largest Maturing Follicle	Number of Eggs in Nest
June 9	-	2	42 mm	-
10	-	5	-	-
19	4	1	-	2
19	3	5	-	-
22	4	1	-	4
July 10	3	3	-	3
11	3	2	-	2
11	3	2	-	3
Aug 9	3	3	-	Hatched

1960 --- Average Season

Date Specimen Collected	Number of Ruptured Follicles	Number of Atretic Follicles	Largest Maturing Follicle	Number of Eggs in Nest
May 22	-	-	7 mm	-
28	-	-	8	-
28	-	-	10	-
28	-	-	8	-
28	-	-	3	-
31	-	-	39	-
31	-	2	43	-
June 8	3	1	-	2

1963 --- Early Season

Date Specimen Collected	Number of Ruptured Follicles	Number of Atretic Follicles	Largest Maturing Follicle	Number of Eggs in Nest
May 20	1	-	20 mm	-
20	-	-	22	2
29	4	-	30	4
30	4	1	-	3

Floods: Spring break-up floods mainly affect snow geese in the midst of egg laying. White-fronted geese are less affected because they usually nest on higher ground, and brant do not usually start nesting in earnest until spring flood conditions have subsided (Figure 63).

Storm tides caused by northwest winds usually occur late in the incubation period. Serious tide damage of nests in the Anderson River Delta is rare because the presence of sea ice offshore throughout June and part of July usually mollifies the wind-pushed tides. Brant, which nest on the lowest possible terrain above normal tide line, and which are the last of the geese to hatch, are the most susceptible to storm tide damage. Some snow geese have been affected also, but the bulk of them had hatched or were nesting on higher ground during the years I recorded storm tide damage.

In 1959, 1962 and 1963 about three per cent of the brant nests were destroyed during late incubation and early hatch by storm tides. There was no storm tide damage in other years of the study. There have been tides high enough to cover the outer, middle, and most of the inner delta but they usually happened in late July, August and September after the young geese had hatched. McEwan (personal communication, 1962) reports that former residents of the Anderson River Delta told him of a storm tide in 1953 that wiped out all the brant and most of the snow goose nests of that season. Hansen (1961) reports extensive storm tide damages to brant nests in the Yukon-Kuskokwim Delta where there is less protection from sea ice than at Anderson River.

Figure 63. Spring break-up flood, Study Area Island.

Arctic Storms: Despite the popular conception of the arctic, storms are uncommon, especially in the summertime. In a typical summer storm for this country, winds seldom exceed 25 miles an hour, but their full force is felt because of the lack of trees and the flatness of the country. Storm winds are from the northwest quadrant, although some of our strongest winds are fair weather easterlies. In the micro-habitat of a goose nest, at ground level, the force of the wind is greatly reduced by friction and the protection of grass and willows. During a storm the temperature usually remains constant between 33° and 39°F. Heavy drenching rain does not often accompany a storm except as a summer cloudburst or as a rare thunderstorm (six in eight years). Ordinarily storm precipitation is a light drizzle or misty rain associated with fog or low scud clouds. Snow squalls occur two or three times during a summer but the snow seldom accumulates on the ground.

Unless they cause flooding, storms during the egg-laying period do little damage. The geese normally tamp and scrunch out a saucer-shaped depression in the soil for the first eggs. Brant often scrape the nest depression right down to permafrost and the first eggs are laid on frozen soil. The temperature of the permafrost and the water-soaked soil around the egg is probably not affected by storms and the eggs can withstand light freezing. Early in the 1963 season, a 20°F temperature lasting for about 10 hours froze and cracked some eggs, but the elastic membrane kept them intact and they survived to hatch. Also, eggs remain dormant until the last one is laid about five or six days after the first, and incubation begins for all at one time.

Storms of the normal intensity during incubation do little damage, either. Incubating geese, of course, sit tight on the nest during foul weather. Thermister probes attached to the eggs of a snow goose incubating during an early spring cold snap maintained an incubation temperature of 75°F to 102°F even while the ambient temperature was 23°F to 32°F and a snow squall drifted four or five inches of snow around her and the nest (Figure 64).

The only storm recorded during the study that actually devastated the nesting grounds was June 24 to 27 in 1964. The entire 1964 season was one of the worst years on record for sea ice. Ironically, the early season weather was better than usual because of the continuous presence of off-shore ice; little moisture in the form of fog and low stratus cloud could be carried in by onshore winds, and clear sunny days helped snow clearance for goose nesting. As a consequence the thaw progressed too rapidly, and about a quarter of the snow goose nests were destroyed by spring runoff floods. Later in the summer, onshore winds over close pack ice and open

leads brought snow squalls approximately every two weeks. The worst storm of the season -- and the one severe storm during the entire nine-year-study -- destroyed the rest of the snow goose nests, about three-fourths of the white-fronted goose nests, and about half the brant nests. It began June 24, with strong northwest winds gusting up to 40 and 50 mph, accompanied by driving rain. The heavy ice was quickly driven as a pack against the Beaufort Sea coast, and the rain turned to snow which formed drifts a foot deep on the delta and up to 2-1/2 feet deep 20 miles upstream.

An activity recorder and thermograph connected to 10 brant nests during the storm showed that even though the ambient temperature at the nests remained between $57^{\circ}F$ and $29^{\circ}F$ during the entire storm the incubation temperature slowly declined as the nests got wet, and one by one the females abandoned (Table V and Figure 41).

Predation: The degree of reproductive failure caused by nest predation can vary considerably from year to year depending on the abundance of predatory species. Aside from such fluctuating species as the arctic fox, there is also a nearly constant number of predators among the gulls and jaegers, etc., which take a nearly constant number of eggs and young each season; slight variations are attributable in some cases to the weather conditions of the season and are discussed more fully in the next section. In Table ~~IX~~ VIII the nests outside the study area were checked towards the end of incubation. Apparent egg loss and nest loss were determined by the number of broken eggs caused by jaegers or signs of foxes caching eggs nearby.

In summary the loss of eggs to jaegers ranges between one and five per cent. Loss of young to gulls also averages about five per cent.

Figure 64. Early snow goose nest that survived a cold snap.

The loss of eggs to foxes and grizzly bear, though irregular, can be as high as 70 or 80 per cent and in localized spots is complete. The loss of young to these mammals is slight.

The physiological reaction of geese to an incomplete reproductive cycle varies somewhat according to the point at which it is interrupted. In late seasons, as mentioned before, the female resorbs some or all of the ripening ovarian follicles and the yolk is probably mobilized for other necessary bodily functions during a period of stress. If the season is late enough and no nesting occurs at all, she and her mate undergo some physiological changes, probably arising from an environmental stimulus, which allow them to advance the date of annual molt and join the flocks of non-breeders. Except in the case of white-fronts, such geese usually leave the area. Thus they regain flight and are in good condition

for fall migration much earlier than if they had nested successfully. Undoubtedly there are selective advantages to this procedure over nesting late and running the risk of themselves and their young perishing in an early freeze-up while still flightless (Barry, 1962).

Nesting failure early in the incubation period, whether caused by floods, predation or storms, leaves the female in a poorer condition than if she had resorbed her ova; still the pair are able to advance the date of the molt and join the non-breeders. Re-nesting attempts are never made because the geese are physiologically (and evolutionarily) unable to do so. Band recoveries indicate geese live 14 years or more. By molting early and eliminating the metabolic drains of continued incubation, brooding, and care of the young, they are in excellent shape for fall migration, and have a much better chance of surviving to nest again the next season.

Nest destruction late in the incubation period or, as is more often the case, loss of young to predators, results in no appreciable advance of the molting date, and the failed nesters remain in the family group flocks to which they were originally attached.

Predation

Predators on geese attack eggs, young and adults. Some predatory species concentrate on only one phase of the goose life cycle while others are able to take geese at any stage. In general, the predation rate is rather constant, but fluctuations of populations of buffer species and hence of predators themselves, as well as varying weather conditions, do affect the predation rate.

Parasitic Jaegers: Of the three species of jaeger seen at Anderson River, only the parasitic jaeger (*Stercorarius parasiticus*) nests in the delta. The literature states that all three jaegers feed on lemmings and what they can steal from such other birds as gulls, terns, loons, etc. This is true, but in the arctic the dominant food of the three species seems to differ. The long-tailed jaeger (*S. longicaudus*), one of the last birds to arrive in the spring, seems to be predominantly an insect eater. The pomarine jaeger (*S. pomarinus*), which passes Anderson River in loose flocks about June 10 to 12 on the way to nesting sites on the Arctic Islands and coast, seems to feed primarily on lemmings. During the short time these two jaegers are at Anderson River they take a few goose eggs, but seem more attracted to our rubbish pile. On Banks Island in 1960 when the lemmings were extremely high in numbers, the pomarine was the most abundant of the three species. In 1961 after the lemming population had crashed to nearly zero, the pomarine jaeger population also dropped to nothing, but the parasitic and long-tailed jaegers remained relatively constant in numbers.

The parasitic jaeger seems to feed mostly on eggs and small birds. They are the first jaegers to be seen at the Anderson River, arriving shortly after the first geese arrive, about May 20. Jaeger predation on geese is concentrated on the eggs, in particular, during the egg-laying period. After the young geese hatch and dry, jaegers seem unable to kill even young strays. Only once have I seen a jaeger kill a young goose (a two-day-old brant).

Observation of jaegers flying over the goose grounds is one of the best ways of telling when and where the first goose eggs are laid. During the egg laying the goose nests are relatively unprotected, although the eggs are cleverly camouflaged. At this time the parasitic jaegers, hunting either singly or in widely separated pairs, skim and soar in their dipping and rising flight from 30 to 100 feet over the goose flats. When they spot a nest they drop directly onto it and scatter the material covering the eggs. This peculiar habit gives the parent birds time to rush to the nest if they are nearby. Brant are more successful than snow geese in protecting their eggs from jaegers because they stay closer to their territory during egg laying.

Once the nest is uncovered, the jaeger quickly pecks a hole in one or more eggs before starting to feed. Once one finds a nest he is joined by others. They are unable to fly off with an egg, so they feed directly at the nest. After incubation begins they find egging more difficult, so they hunt in pairs or in teams of up to five birds that swoop and dive at incubating geese in attempts to distract them long enough to poke holes in the eggs. As this becomes unsuccessful, with the greater attentiveness of the geese later in incubation, the jaegers wander further afield after other prey, particularly the nests of shore birds, ptarmigan and glaucous

gulls which are more exposed than those of passerines. Jaegers also kill young shore birds, ptarmigan and passerines. Once I saw them harrass and kill a slightly injured knot, and again a lapland longspur.

Jaeger predation on eggs is fairly constant. However, in 1959 when ice cover forced the brant to nest in marginal habitat, and in 1964 when floods forced snow geese to move to new habitat, jaeger predation increased considerably. I can only speculate on the reasons for this: the unfamiliar nest sites seemed to make the geese lackadaisical about nest defense; they often stood by, about 30 feet away, and watched as jaegers tore their nests apart. At times the parent geese would rush the jaegers after the damage was done. In the case of the snow goose, nests were built to complete partial clutches lost in the flood; this may have had a bearing on their apathetic response.

Glaucous Gulls: These birds, which number about 200 in the delta, take over predation when the jaegers move off, namely when the young geese hatch. The almost total absence of egg predation by glaucous gulls (*Larus hyperborea*) came as a surprise to me after watching the egging ability of herring gulls (*Larus argentatus*) which took 27 per cent of Atlantic brant eggs at Southampton Island (Barry, 1956). During egg laying and incubation glaucous gulls feed almost entirely on aquatic animals; remains of small herring and other fish, lamprey ammocete larvae, and a species of large marine isopods make up the bulk of food items collected from gulls at this season. Holmes (personal communication, 1961) reports glaucous gulls to be egg predators on Kendall Island, and Swartz (1966) lists them as egg predators in sea bird colonies of the Cape Thompson cliffs in Alaska. I have only two records of them feeding on eggs in Anderson River Delta: a

gull seen flying with an unbroken egg in its beak, and another observed pulling a brant egg out of a nest on Gull Island and eating the contents. Gulls often molest brant nests, but generally the apparent purpose is to steal the down for their own nests. On Gull Island this is a frequent event without attendant egg predation, and usually the down is taken from nests already destroyed by jaegers.

The glaucous is the largest of all the gulls and is capable of killing young snow geese up to four weeks old by pecking through the skull or the upper flanks in the area of the liver and kidney. Younger geese, up to one week old, are snatched up and swallowed whole. The fantastic digestive power of the gull is illustrated by one I shot a few moments after it had swallowed a young brant; the head of the victim was almost completely digested while the down on the rump was still dry.

Behavior and calls of the gulls indicate when the first young geese have hatched. Up to this point they have been hunting the water courses; as soon as the hatch begins they are seen hovering and swooping over the goose flats. Glaucous gulls also hunt singly or in groups of up to five birds, but never do they show the teamwork of parasitic jaegers or herring gulls. Their attack is usually a low-level dash to pick off a straggling young. If a gosling is completely separated from the brood, they hover 20 to 50 feet above it and drop on it. If the isolated gosling is in the water, the gulls force it to dive until it is exhausted and can be given a killing peck on the back.

<u>Golden Eagle</u>: Besides the pair that regularly nests at South Bluffs, golden eagles are also found at Husky Bend, Mason River and along the Liverpool Bay coast to Kugaluk and Smoke rivers. Periodic checks of the

South Bluffs nest and roosting sites show they seem to feed on one species of prey at a time, although the choice is not related entirely to availability. For instance, muskrats are quite rare in the Anderson River Delta compared with other available food, yet for a while only remains of muskrat were found at the nest. The main food items of the eagles are arctic ground squirrels, ptarmigan, geese and swans, but they take surprisingly few ducks.

One of the preferred gathering places of the geese in early spring is the island between South Bluffs and the end of Fox Den Island. It is an impressive sight to watch the eagles soar out from the bluffs to stoop on the goose flocks, putting 10,000 or more to flight. I have never seen eagles make a kill on the wing; instead they always try to pounce on their prey on the ground. The geese know when the eagles are hunting and take flight at once.

In 1963, incubating snow geese were hit hard in one place on Triangle Island where I flushed an eagle off a fresh goose carcass. I found eight females had been killed on the nest and eaten to a varying extent on the spot. I have no record of adult snow geese or white-fronts being carried back to the nest, but the records of eagle-killed geese were made before the two young eaglets hatched, so there would be no reason to carry back food.

After the eaglets hatched, carcasses are brought to the nest. One day in 1963 it contained five 2-1/2-week-old snow geese, a white-front gosling, and an adult brant weighing about three pounds (Figure 65). Another time, there was a leg bone of a young swan; the swan weighed nearly eight pounds when we banded it, so I doubt the entire carcass was carried to the nest.

Figure 65. Young golden eagle in nest with carcasses of young geese and brant.

Snowy Owl: These owls are rare in the delta in the summertime; the lone snowy owl that spent the early summer of 1962 on the North Bluffs appeared to feed only on incubating female brant which it killed on their nests. It took an average of one brant every 2-1/2 days. Snowy owls are more abundant on Banks Island when the lemming population is high, but I have no record of their killing brant or snow geese there. Uspenskii (1965) places considerable stress on the importance of snowy owls in protecting neighboring geese from foxes, glaucous gulls and jaegers. This relationship of geese nesting near raptors has been observed by Kessel and Cade (1958) for Canada geese, and Uspenskii (1965a) for red-breasted brant (Branta ruficollis), and others.

Peregrine Falcon and Gyrfalcon: These two falcons are common in the delta but neither appears to feed on geese. There is an eyrie of peregrines on the South Bluffs about 1-1/2 miles upstream from the eagle's nest; gyrfalcons nest in trees and cliffs upstream and on some of the bluffs on the east end of Liverpool Bay. When either of these falcons fly over the delta the geese pay little attention, but the shore birds, especially if in flocks, scramble for cover as do ptarmigan.

Short-eared Owl: Appearing with uncanny regularity during years of microtus abundance, short-eared owls show little inclination to take young geese but do seize almost any small animal that moves in the inner delta and willows. One owl nest had a one-day-old white-front as well as four young white-crowned sparrows and seven microtus.

Marsh Hawk: The numbers of marsh hawks is nearly constant from year to year regardless of the population of rodents, one of their main foods. Besides voles, these inhabitants of the ptarmigan willows and the inner delta feed on ptarmigan, ducklings and a few white-fronts, but they are a minor factor in goose predation.

Some of the mammalian predators on geese are the most destructive, and under certain conditions can be decimating.

Arctic Fox: During the first few years of the study a pair of arctic foxes maintained a den on the edge of the snow goose habitat on Fox Den Island in the middle delta. They proved to be restless, thorough predators, especially on brant and snow goose eggs. They are not large,

weighing from five to 15 pounds at most, and waterfowl larger than brant can drive them away. The swans nesting across the channel from the house claimed the south end of Study Area Island for their territory, and always chased the fox as he tried to sneak by along the bank going to and from the den. Foxes avoid swimming if they can, but this one was often forced into the runoff channel by the charging swans. Snow geese also are large enough to drive off a fox, but most are content to sit by while a fox robs a neighbor's nest. McEwan (1958) describes this behavior in Banks Island geese, too.

Like jaegers, foxes rob snow geese mostly during egg laying when the nests are loosely guarded; once incubation starts the opportunities are fewer. Even so, foxes may be considered far more destructive than jaegers because of their habit of caching eggs in frost cracks or burying them in the mud. Should a fox catch young snow geese away from water, it quickly kills as many as possible and caches the carcasses. After a banding drive in 1960 we found 10 cached young snow geese on Fox Den Island near where we had herded 1,600 snow geese for banding and had temporarily broken up family groups.

Brant are too small to stand off a determined fox, however spunky they might be. Twice I watched a fox catch adult brant from among newly arrived flocks and carry the carcass over the ice to the den. Later I watched a pair of brant in the study area put up a valiant but ineffective defense of their nest and six eggs: the birds stood over the nest with wings outstretched, uttering threatening growls while the fox circled about six to 10 feet away before making a sudden rush and the brant jumped nimbly aside. The fox grabbed an egg on the run, and carried it 30 feet away where he buried it intact, pushing the mud over it with his nose.

The maneuver was repeated until all the eggs were taken and cached, whereupon the fox moved on to the next brant nest. In this fashion the fox cleaned all the eggs out of 112 incubating brant nests in about four days. He ate only about five per cent of the eggs and cached all the rest.

1960 was a year of very high lemming and fox populations on Banks Island; the 1959-1960 season yielded about 6,500 foxes to the Sachs Harbour trappers. Lemmings declined sharply the following winter, but the foxes managed to survive, probably on cached food, and the winter's take of fox pelts was still nearly 5,000. By spring, although foxes were still abundant, there were virtually no lemmings. Weather conditions for the spring of 1961 suggest that it should have been an excellent year for snow goose reproduction, but as it turned out an average of only one young per pair reached flying stage. The most likely explanation for the poor productivity is that the foxes were feeding extensively on goose eggs and young geese.

I assume that the presence of the active den on Fox Den Island finally caused most of the snow geese there to move to Triangle Island for the nesting season of 1961. There was little snow cover that spring to hinder nesting, and the geese abandoned nearly all their usual sites along the ridges of Fox Den Island. In 1959 the 10 inches of ice deposited on Brant Island during the previous fall, forced the brant to nest in the snow goose area of the middle delta. This change of habitat met with disastrous results because foxes robbed virtually all of the nests of eggs. The foxes did not have to swim to get to the brant nests as they would have at Brant Island.

<u>Barren-ground Grizzly Bear</u>: Bears are not regular predators on geese but once one stumbles onto a goose colony it usually stays a few days to eat eggs. We have seen from one to 30 bears per season from 1958 to 1966 (Figure 66).

Bear damage to a goose colony can be extensive. On the morning of June 28, 1958, I discovered two adult grizzlies on my study area; they stayed in the delta for six days and could easily be observed at any time. Simultaneously, there were two other bears on the hills of the southwest side of the delta but they did not come out onto the goose grounds. The two in the goose colony were mutually antagonistic and seldom approached within a half mile without one chasing the other. Whenever it was safe I continued nest checks, collected scats and followed tracks.

Figure 66. Barren-ground grizzly bear.
Photo by R. Fyfe.

The bears first ate pipping eggs and newly hatched young of snow geese, then moved to the brant habitat in the outer delta where they zigzagged randomly through the colony, eating the contents of every nest encountered. By the time they left the delta they had destroyed 95 snow goose and 80 brant nests on the study area itself, as well as at least 65 snow and 55 brant nests elsewhere, representing altogether about 37 per cent of the snow and brant nests found in the eastern section of the Anderson Delta that year. From five to 10 per cent of this damage was the work of attendant glaucous gulls, parasitic jaegers and ravens (*Corvus corax*) preying on nests temporarily abandoned by geese the bear had frightened.

In addition to eggs and young of geese, the bears took at least five female king eiders, which I saw batted down as they froze on the nest. After eating a duck, a bear would clean out the nest before moving on. One bear charged into a flock of snow geese he could easily have caught had they then been molting.

Red Fox: A creature of the ptarmigan willows and the inner delta, the red fox primarily feeds on ptarmigan, passerines and voles of this habitat. They have never been seen among the snow geese or brant except in early spring when the river is still frozen. Inland, the red fox is probably the main predator on white-fronted goose eggs and young, and being larger than the arctic fox, may be able to take adult white-fronts as well. It is most often seen cruising the shores of tributary streams and river channels where white-fronts are most apt to be found. In the inner delta I found the remains of three still warm young white-fronts cached on the side of a levee in a stand of willow (*Salix alaxensis*).

Wolf: Wolves make regular patrols of the river valleys and the coastal beaches of Wood Bay and Liverpool Bay. An exceptionally large white one with distinctive tracks passed up and down the river every 10 to 14 days for four seasons. They do not go out of their way to visit the goose islands, and I have only two records of wolves appearing on brant and snow goose grounds. One obviously followed a caribou from Kettlehole Point to Oil Drum and Gull Island, taking eggs from nests of glaucous gulls, brant and snow geese as he went. The other, which hung around our camp for three or four days when our bitch Chesapeake retriever was in heat, crossed over the ice to Fox Den Island where it took about 10 fresh goose eggs.

Wolverine: The only wolverines I have seen in the outer or middle delta or in the ptarmigan willows appeared in winter or in early spring before break-up. They have broken into the abandoned church at Stanton, and in 1965 one lived under a cabin while feeding on the carcass of a grizzly bear I was forced to shoot near the doorstep just before freeze-up the previous fall. Wolverine are fairly common in the inner delta where they apparently prey on ducks and shore birds. The stomach of a young female shot there in 1961 contained the bills of five pintail drakes.

Mink, Marten and Weasel: All occur in the ptarmigan willows, inner delta and upstream, but I have no record of them feeding on geese. Ducks, shore birds and passerines are probably their main avian fare.

Man: As mentioned earlier, the human population and its pressure on the natural resources of the Anderson River valley has declined dramatically

in the past 100 years. With this decline, the most hunted species have largely regained their numbers. Most of the nesting grounds of arctic geese are still remote and have yet to suffer serious disturbance by man. In fact, with the establishment of sanctuaries for the major goose nesting areas in Canada, USA and USSR, and the decline of egg-gathering by native people due to economic and cultural changes, the geese have a better chance of being undisturbed on their chosen nesting habitat than 30 years ago.

For an account of the impact of egging, see Mineyev (1946) and Portenko (1937). I have seen such egg-gathering at Southampton Island where in 1956 a man told me of gathering more than 1,200 eggs (approximately 240 pounds) and 100 geese in one day. This was before the East Bay Migratory Birds Sanctuary was established. Today, although spring shooting still persists in a few areas, gathering of goose eggs is nearly a thing of the past.

Defensive Behavior: Methods of defense against predation varies with each species of goose and is according to the mode of attack by the particular predator.

Brant are too small to cope with arctic foxes, but they achieve a degree of safety by nesting on islands a fox must reach by swimming. Brant with young or in the molt stay close to shore and are quick to head for the water on approach of danger.

Against jaegers, brant often are benefitted by such nesting associates as the arctic tern which aggressively harass avian predators on the prowl for eggs. The male brant also will fly escort to passing jaegers. During egg laying brant tend to stay close to their territories and are more effective than snow geese in rushing back to an endangered nest. During

incubation the male brant comes up to the nest and the pair head-poke and utter threat calls if under team attack by jaegers. Later, with young, they bunch into tight family groups or flocks to stand off gull attacks with many head-pokings and threatening growls; usually only the stragglers or broken-up flocks suffer loss to gulls.

Snow geese are large enough that they can usually drive an arctic fox away from the nest. Snow geese normally wander from their territory during egg laying so that a fox or jaeger could take eggs with little contest from neighboring pairs which seldom bother a predator outside their own territory. However, new nests of snow geese are usually well-concealed; by the time the conspicuous down is added to the nest, the geese are staying closer to the territory.

Defense of incubating snow geese against jaegers and foxes is similar to that of brant: the male comes up to the female at the nest, and the two face the attackers uttering "baa-ing" threats. Often they stand tall, spread their wings and ruff up their breast feathers as brant and white-fronted geese also do on occasion.

Snow geese with young bunch into tight flocks or family groups and, uttering threat calls, present a formidable mass to gulls or foxes. Often they move toward water at the same time.

White-fronted geese protect their nests by wide dispersal and by the natural camouflage of their plumage. Their main predators are mammals, and the "yea chorus" of yearling birds effectively distracts these prowlers from the nest.

When the young are less than two weeks old, white-fronts also are inclined to bunch up for protection. The parents assume a characteristic tail-up breast-down posture, exposing the white patches of the lower belly

and undertail coverts as an alarm signal. Simultaneously, a low call is made, and the young gather close by the parents. The "white alarm" has probably proven advantageous in the scrub willow of the inner delta where otherwise the parent birds would be hard for the young to see. Brant and Canada geese use a similar posture, but to a lesser extent.

Later, white-front families scatter as a defense tactic, but the young, while seeming to be easy picking for gulls, are superb divers and are expert at vanishing in thick willow scrub. The individualistic behavior characteristic of white-fronts usually results in the sacrifice of one or two members to a predator while the rest survive. If they stayed as a unit the usual mammalian predators could take them all.

Food Habits

The section on flora and fauna and the list of plants in Appendix A show the general distribution of plants within the 10 habitat or floristic-geographical areas into which I have divided the Anderson River Delta. It is probably more than mere coincidence that the most frequently used food plants are the most abundant in the particular nesting or molting areas of each of the goose species. The geese have evolved their nesting niches and food preferences concommittently, resulting in minimal competition for food at the present time.

Figure 67 shows the comparative sizes of grit used by the three species. This probably reflects the type of food used by the geese. *Carex subspathacea*, the main food of brant, is fine and soft compared to the coarser foods of snow geese and white-fronts, and may explain why brant have such a high percentage of fine grit in their gizzards. Larger sizes are not necessary to grind up their ordinary food.

Food habits of adult geese change during the nesting season (Table X) apparently because of varying availability, ripeness or succulence of food items. For example, in May, snow geese mostly use the grass *Elymus arenarius* which is so abundant in their nesting zone. Not only is it available, but also it is quite soft and succulent. But by June, when elymus becomes hard and tough, it drops low on the list. Snow geese, incidentally, seem to be the most catholic in their tastes of all the geese.

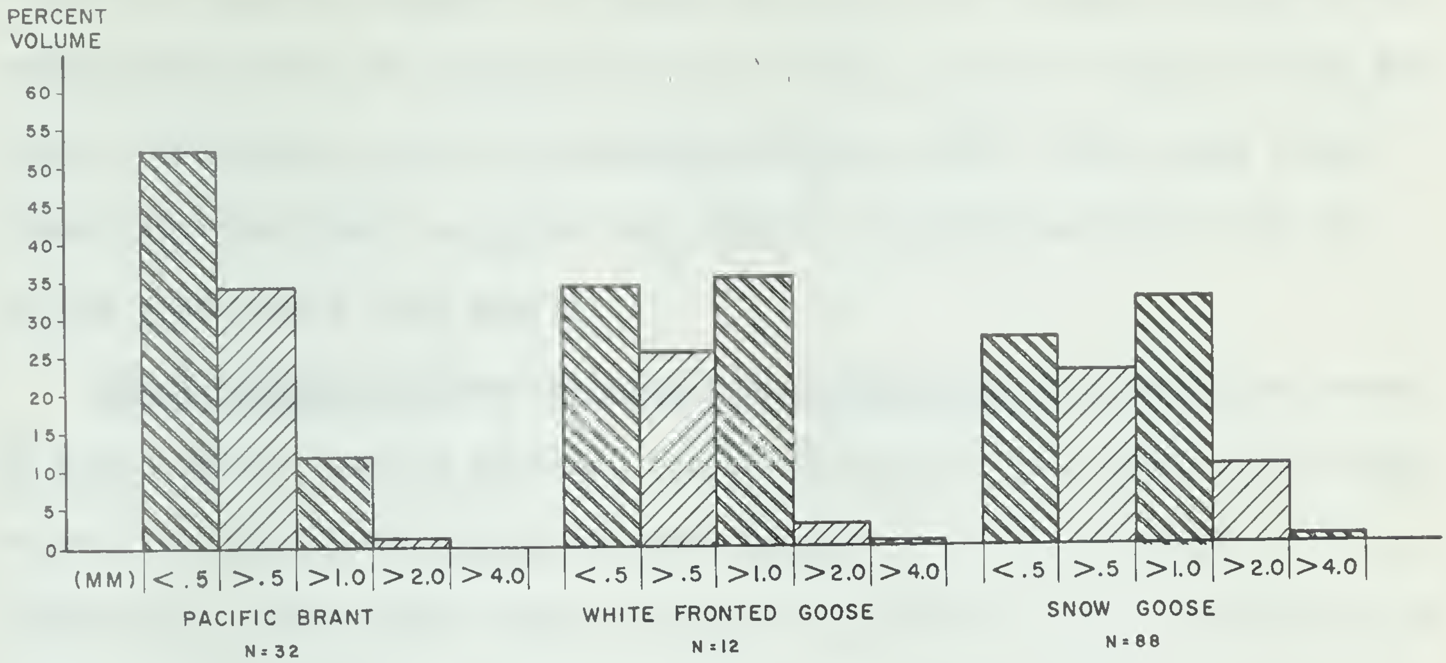


FIGURE 67, GRIT SIZE IN GOOSE GIZZARDS

In the white-fronted goose habitat, Carex aquatilis is readily available and, being semi-aquatic, remains succulent almost throughout the season. Equisetum is a food favored by all geese; it is interesting that Uspenskii (1965a) observed that equisetum is used heavily by molting white-fronts in the USSR, as it is at the Anderson River Delta, where it tops the list for the July molting period. Uspenskii also lists Eriophorum angustifolium as the chief food of white-fronts, along with Arctophila fulva, Carex stans and Atropis angustata, all plants of the type common to the inner delta of the Anderson River, the zone occupied by white-fronts.

As for brant, their nesting grounds present them with more drastic changes than are experienced by snow geese and white-fronts. Brant become

land grazers and drink fresh water, at least during the months of June and July and part of August. During the rest of the year, they feed on marine plants such as eelgrass and sea lettuce, and are able to drink sea water. Like other sea birds (Schmidt-Nielsen, 1958), brant have a salt gland (the two lobes lie above the orbit of the eyes and cover the top of the skull where they meet).

Carex subspathacea and *Puccinellia phryganodes*, the preferred foods of brant on the nesting grounds, require occasional sea water submergence to survive; the distribution of these plants in the Anderson River Delta follows the yearly storm tide line, which is also the main nesting area of the brant. On arrival, brant also gather in runoff channels to feed on debris and broken off fronds of overwintered *Potamogeton vaginatus* probed out of the bottom ice by swans. They feed rather delicately, picking bits off the surface much as if it were eelgrass. Some tip up, as they do at the Izembek Bay eelgrass beds. Later, in July and August, brant return with their young, to the potamogeton beds, where they exhibit a periodic feeding behavior controlled by the tidal exposure of fronds and seed heads.

The molt migration of geese may be an effort to find new feeding grounds. White-fronts move to the lush marshy prairies of the inner delta. Snow geese move to the edge of the inner delta or to the outer delta. Brant move within their habitat, but to sections where they could not nest because of the presence of predators.

The effect of plant nutrients derived from animal dung or other organic sources is always striking on arctic soils, where vegetation is usually sparse, dwarfed and starved. Because of low soil temperatures, the dry climate and the short summer, bacterial action and decay are extremely slow and the fertilizing effect of animal dung, carcasses and skeletons

continues for a considerable time. Evidence of the fertilizing effect of the droppings of geese is plain to see in the particular lushness of the vegetation on nesting sites, and in the meadows and lakeshores where the geese feed (Porsild, 1955). Nitrogenous remains of invertebrates from goose droppings, those of young geese in particular, probably also contribute much to fertilization of plants.

The effect of the geese on the goose meadows is probably best shown on Banks Island or on newly-emerged littoral bands, such as those of the Boas River Delta, Southampton Island. From the air such meadows look like lush oases amid barren expanses of soil. Tikhomirov (1959) describes the damage large flocks of geese can do to tundra meadows, but he seems to ignore the fertilizing effect of geese. The concentration of geese near bodies of water in the tundra considerably affects plant growth along the shores. There, dense stands of sedges and grass such as Arctophila fulva and Dupontia fisheri are usually eaten by the geese; reproductive parts of these plants are non-existent as a rule, and the vegetation is cut low to the ground as if by shears. Uspenskii, Beme and Velizhanin (1963) remark that the tundra on Wrangel Island is almost completely trimmed by snow geese, feeding principally on Dupontia fisheri and Pleuropogon sabinii. The somewhat lengthy stay of the geese near bodies of water during the molting period changes the shore regions where a considerable quantity of goose scats accumulate. It is interesting that on Brant Island the nitrate in the soil is highest where large numbers of brant nest and their young are reared (Table I).

Table X. Food habits of adult geese,
Anderson River Delta, N.W.T.

Snow Geese

May: N= 22; Total volume, 193 ml.

Elymus arenarius	22.8%
Cyperaceae sp.	20.7
Carex sp.	19.7
Carex subspathaceae	13.0
Arctophila fulva	8.7
Unidentified	4.7
Dupontia fisheri	4.1
Gramineae sp.	2.6
Eriophorum angustifolium	2.1
Puccinellia phryganodes	1.6

June: N=19; Total volume, 279 ml.

Carex aquatilis	16.8%
Salix arctica	15.0
Dupontia fisheri	14.8
Eriophorum angustifolium	10.0
Gramineae sp.	8.2
Carex sp.	7.5
Cyperaceae sp.	5.7
Carex lugens	5.4
Vaccinium vitis-idaea	3.2
Unidentified	3.0
Equisetum variegatum	2.5
Equisetum arvense	2.5
Carex subspathaceae	2.5
Elymus arenarius	2.2
Egg shells	1.2

July: N=12; Total volume, 58 ml.

Carex subspathaceae	43.1%
Carex maritima	19.0
Dupontia fisheri	19.0
Eriophorum angustifolium	13.8
Puccinellia phryganodes	1.7
Anemone parviflora	1.7
Unidentified	1.7

August: nil.

Table X continued.

Snow Geese

September: N=36; Total volume, 714 ml.

Carex aquatilis	54.3%
Equisetum variegatum	17.4
Eriophorum angustifolium	10.5
Carex sp.	6.3
Dupontia fisheri	4.5
Elymus arenarius	2.1
Gramineae sp.	1.8
Hippuris vulgaris	.8
Arctophila fulva	.7
Empetrum nigrum	.4
Unidentified	.4
Eleocharis acicularis	.4
Potamogeton vaginatus	.2
Salix sp.	.2

Pacific Brant

April: estimated
(California to British Columbia)

Zostera marina	50.0%
Ulva sp.	50.0

May: N=2; Total volume, 5 ml.
(Anderson River Delta, NWT)

Carex subspathaceae	60.0%
Dupontia fisheri	40.0

(most specimens empty)

June: N=13; Total volume, 136

Carex subspathaceae	62.50%
Hippuris vulgaris	17.60
Puccinellia phryganodes	6.60
Equisetum arvense	3.70
Carex sp.	2.90
Arctophila fulva	1.47
Dupontia fisheri	1.47
Unidentified	1.47
Gramineae sp.	.70
Insects	.70
Salix sp.	.35
Potentilla sp.	.35

Table X continued.

Pacific Brant

July: N=10; Total volume, 143 ml.

Carex subspathaceae	53.1%
Dupontia fisheri	21.7
Puccinellia phryganodes	9.1
Hippuris vulgaris	7.9
Elymus arenarius	3.5
Carex ursina	3.5
Potamogeton vaginatus	1.4
Equisetum arvense	.7

August: N=5; Total volume, 16

Carex subspathaceae	62.5%
Potamogeton vaginatus	31.3
Dupontia fisheria	6.2

September: N=2; Total volume, 6

Unidentified	50.0%
Carex subspathaceae	33.4
Moss	16.6

White-Fronted Geese

June: N=1; Total volume, 23 ml.

Carex aquatilis	56.5%
Arctophila fulva	43.5

July: N=5; Total volume, 127 ml.

Equisetum arvense	58.3%
Carex lugens	29.1
Potamogeton vaginatus	11.8
Salix sp.	.4
Moss	.4

August: N=6; Total volume, 108 ml.

Carex aquatilis	50.9%
Potamogeton vaginatus	20.4
Equisetum arvense	18.5
Cyperaceae sp.	9.3
Eleocharis acicularis	.9

Summary Discussion

The Anderson River Delta from the north end of Nicholson Island to Husky Bend concentrates a wide range of arctic environments. Exceptional variations in the delta's environment permit a wider range of flora and fauna than is usual elsewhere in the arctic. Because of the interspersion of many habitat types, lists of species are marked with the "furthest north" records of many southern species along with truly high arctic species.

The general arctic environment is a condition to which Pacific brant, snow geese and white-fronted geese have adapted themselves. Many adaptations are common to the three species, and have evolved to shorten the time necessary on the nesting grounds. Their annual migrations are synchronized to bring them from widely scattered wintering grounds via different routes to the Anderson River Delta at the most advantageous time for nesting.

As the geese migrate north they are moving into a region of longer and longer days, and eventually of continuous daylight. Migration begins by their following the progress of the spring thaw north, but this changes as they reach the longer days, beginning at about latitude 55°N. Once they enter the zone of continuous light, their rate of migration accelerates rapidly. They press on, passing the northward advance of spring as they fly into the Arctic, usually non-stop for at least several hundred to a thousand or more miles. Their gonads have developed to a peak of sexual maturity by the time they reach their last staging areas on the edge of continuous daylight.

At Anderson River no time is wasted on elaborate courtship rituals or on copulation; these events have been accomplished already. Daylight stimulates gonad development, and the control of breeding has probably been evolved in arctic geese to such an extent that nearly continuous daylight is necessary for copulation. In addition, the traditional migration routes and staging areas bring the birds together at the appropriate time near the open water necessary for copulation. The presence of many other geese in the same excited state is probably the final environmental stimulus to copulation (Marshall, 1961).

When the geese arrive on the nesting grounds, all their efforts are directed toward successfully raising a family. But if the environment happens to be hostile and they cannot nest within a limited time, they short-cut the remaining reproductive events, molt early, and spend their time getting in good condition, thus aiding their chances of trying again another year.

In addition to their somewhat similar adaptation to the Arctic, each species has selected its own zone or niche within that environment, and has evolved habits that fit the preferred habitat. The typical brant nest site, for example, is on low flat soggy ground, the last to clear of snow and water, so there is no advantage in their arriving on the nesting grounds early. Usually there is little vegetative material present, so the thick down and the depression in the turf become the most important parts of the nest. The down hides and insulates the eggs and can withstand the usual blustery weather of the brant habitat.

Snow geese use higher, drier ground with taller vegetation for nest sites. They build nests of the surrounding grasses and willows, and use sparse down interwoven with the nest material. It does not need to be cohesive.

White-fronts nest on still higher and drier ground, often in rather thick cover, using very little down and only a sparse amount of twigs and grass. Natural seclusion and wide dispersal serve as protection enough.

The normal predators on each of the three species seem to affect the niche and to some extent the defensive behavior of the geese. For the snow geese, which I consider true colony nesters, defense is in numbers. Their grounds must be large and flat enough for each goose to see what is going on. Defensively, they herd together into amazingly tight packs.

Brant are sea or island geese because they are too small to bluff the arctic fox, an animal that must be extremely hungry before it is willing to wet its feet. Hence, brant are usually safe on outer islands which are too low and soggy for fox dens, while it is possible for foxes to den in snow goose habitat.

White-fronted geese nest beyond the usual summer range of the arctic fox, but must contend with the larger red fox, an animal too big to be driven from the nest. Still larger mammals, like the wolverine and bear, also roam the white-fronts' zone. To counter these predators, they disperse their nests, their young and themselves, and the young of prior years are enlisted to set up noisy diversionary tactics to confuse their large enemies. The larger clutch size of white-fronts indicate they are prepared to sacrifice some young for the safety of others.

The different food habits of the geese also show adaptations to their definite niches. Goose flocks seldom mix, and even when seemingly close together there is a subtle vegetational or geographical line separating them. Where an overlap of foods occurs, such as snow goose broods, as well as brant, feeding on brant grass (Carex subspathacea), either there is an abundance of the food item or the other species of goose has already left for other pastures.

Factors of geography, vegetation and predation resulting in habitat niches with which the Anderson River Delta geese are associated may be summarized as follows:

	Pacific Brant	Lesser Snow Goose	White-fronted Goose
Geographic Features	Newly formed delta islands subject to flooding.	Higher, drier than brant habitat; early snow clearance; large flat areas.	Higher, drier floodplains with interspersed streams and sloughs.
Vegetative Features	Pioneering plants (carex and turf grasses) requiring salt water submergence.	Lush grasses and sedges; vegetation low enough so vision is not obscured.	Scrub willows, with interspersed sedges and grasses.
Predation	Susceptible to arctic foxes; require islands.	Depends upon colony defense.	Diversionay protection by members of family group; individual escape with dispersal; excellent protective coloration and heavy cover for hiding.

The major evolutionary pressure on arctic nesting geese is the weather. With physiological development and the build up of fat reserves synchronized to the average season, the geese are well adapted to the arctic environment. But variations from the average season have more profound effects on goose populations than any other environmental factor. The terms "early" and "late" seasons are only relative to the so-called "average" season. Arctic meteorological records have been kept for only a few years, so it is barely possible to arrive at a statistical "average." For the geese, however, meteorological average seasons have been impressed into their yearly cycle through thousands of years of the selective pressure of evolution.

Providing no late spring floods occur, only about five to 10 per cent of the habitat needs to be cleared for geese to begin nesting with normal

chances of success. But in some years, even this small amount of cleared land does not appear until after the nesting period to which the birds are synchronized has passed. The entire nesting cohort of each of the three species has about 10 days for nest initiation, and once this period has passed, with still no nest sites available, the reproductive attempts for that season are stopped; few if any young will be among the fall flocks. The further the late season cuts into this nest initiation period, the fewer eggs will be laid; developing eggs in the ovary become atretic and are resorbed so the clutch size is smaller.

Geese are determinant layers; if the season is exceptionally "good" the clutch size will be the maximum number of eggs the female is capable of laying, but never more. This variation in numbers of eggs per nest between "good" and "bad" seasons can have a considerable influence on the total production by the population, and it is this element that so greatly affects the numbers of geese in fall flocks migrating south. The differences in population counts can be accounted for by the number of young produced, which has given rise to the terms "boom" and "bust" seasons for geese.

Once reproduction has failed, whether because of late season, floods, or predation, the geese undergo rapid physiological change, the mechanics of which are unknown. Failed breeders begin their molt early and are able to regain weight and get into peak condition for migration, and so are assured of better chances for survival until the next nesting season. They are free to act as individuals, rather than as members of family groups.

Growth rate of young geese is not only exceptional compared to more southerly species, but it is a necessity if they are to regain flight in

time to escape freeze-up or at least the covering of their food by snow. Mere flight is not enough; the young geese must be sturdy enough to fly over the belt of taiga, which generally has few habitats with good quality food. The time ADDITIONAL spent in pre-migration staging areas is a luxury; the longer they can stay there, the better shape they are in for the fall migration.

From what we know of the arctic nesting environment of geese, I think it is now possible to work out a fairly reliable system to predict by early or middle June their probable reproductive success and what the trend of the fall and winter populations will be. Weather reporting and forecasting, aircraft travel, and communications have improved to the point where knowledge of the environment of the goose grounds can be used to better manage the species before the fall flight rather than by post-morteming the nesting and fall hunting seasons sometime during the following winter. To me, the latter procedure is a ritual that contributes little to the conservation or management of arctic nesting goose.

For me, the calls from a migrating flock of geese stir feelings about remote places, many horizons away. Remoteness is certainly a feature of the realm of arctic geese, but development is pushing close upon them. The economy of the north is changing; egging is nearly an activity of the past, but the geese of the Anderson River Delta have already heard the blast of an oil seismic test. I share a certain personal pride in saying that about 95 per cent of the snow goose grounds, 75 per cent of the brant flats, and 45 per cent of the white-fronted goose nesting areas, as well as the habitats of most other arctic nesting geese, from Wrangel to Baffin Island, are protected by a series of sanctuaries in the USSR, USA and Canada. Can as much be said for their winter haunts?

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Appendix A

Flora of the Anderson River Delta, N.W.T.

Key

1 Wood Bay Beaches	6 River Islands	P Present
2 Outer Delta	7 Ptarmigan Willows	X Rare
3 Middle Delta	8 Hilltops & Nicholson I.	XX Scarce
4 Inner Delta	9 Cliff Faces	XXX Common
5 Tributary Streams	10 Upstream River Banks	XXXX Abundant

Family - Species Zones:	1	2	3	4	5	6	7	8	9	10
Equisetaceae										
Equisetum arvense	XX			XXX		XXX	XXX			
Equisetum limosum					XX					
Pinaceae										
Juniperus communis										P
Sparganiaceae										
Sparganium hyperboreum				XX	VA					
Potamogetonaceae										
Potamogeton gramineus				X		XX				XXX
Potamogeton porsildiorum				XX						
Potamogeton vaginatus			XXXX	XXXX	XXX	VA				XXXX
Potamogeton strictifolius				X						
Juncaginaceae										
Trigolochin maritima			X							

Appendix A (continued)

Family - Species Zones:	1	2	3	4	5	6	7	8	9	10
Gramineae										
Agropyron serviceum								XXX		P
Alopecurus alpinus		X						P		P
Arctagrostis latifolia		XX		XXX	XXX	XX	XX	XX		XXX
Arctophila fulva		XXX				XX				
Bromus pumpellianus						XXX				XXX
Calamagrostis dechampsioides		XX								
Calamagrostis neglecta			XXX							
Calamagrostis purpurascens										XXX
Deschampsia caespitosa				XX		XXX				P
Dupontia fisheri		XXX	XXX	XXX		XXX				
Elymus arenarius	XXXX	XXX	XXXX			XX				P
Elymus innovatus										P
Festuca rubra		XXX				P				P
Hierochloe alpina										P
Phippsia algida								XX		
Poa alpigena							XX	P		
Poa glauca						P				XXX
Puccinellia langeana			XX							
Puccinellia phryganodes		XXXX								
Puccinellia vaginata	P									

Appendix A (continued)

Family - Species Zones:	1	2	3	4	5	6	7	8	9	10
Cyperaceae										
Carex aquatilis			XXX	XXXX	XXX	XXX	XX			P
Carex capillaris				XXX	P					P
Carex consimilis							XXX			
Carex lugens					P		P			P
Carex maritima								P		
Carex membranacea				XX			XX			P
Carex physocarpa			P	XX						
Carex rariflora				XXX						P
Carex rotundata							XXX			
Carex rupestris							XXX			
Carex scirpoidea				XXX	P					P
Carex subspathacea		XXXX	X							
Carex ursina		P								
Eleocharis acicularis				XX	XXX					
Eriophorum angustifolium	XX	XX	XX	XXXX			XX	XXX		P
Eriophorum brachyantherum										P
Eriophorum callitrix							XX			
Eriophorum scheuchzeri				XX				P		P
Eriophorum vaginatum								XX		
Kobresia myosuroides								P		

Appendix A (continued)

Family - Species	Zones: 1	2	3	4	5	6	7	8	9	10
Junaceae										
Juncus arcticus										XX
Juncus balticus		XXX								P
Luzula confusa		XX		XX						P
Liliaceae										
Allium schoenoprasum							X			XX
Tofieldia pusilla				X						
Zygadenus elegans										P
Orchidaceae										
Habenaria obtusata				X						
Salicaceae										
Populus balsamifera										P
Salix alaxensis				XX	XXX	XX	XX			XXX
Salix arctica		XXX	XXX	XXX			XXXX	P		
Salix arctophila	XX	XX					XXX			
Salix barclayi										XXX
Salix brachycarpa										XXX
Salix glauca							XXX			XXX
Salix niphoclada			XX			XXX	XXX			
Salix pulchra	XX			XX			XX			XXX
Salix reticulata							XXX			
Salix richardsonii						XXX	VA	XX		XXX
Betulaceae										
Betula glandulosa							XXX	XXX		P
Corylaceae										
Alnus crispa				XX	XX					XX

Appendix A (continued)

Family - Species Zones:	1	2	3	4	5	6	7	8	9	10
Polygonaceae										
Polygonum caurianum						XX				
Polygonum viviparum				XX				P		
Rumex arcticus		P		XX						
Rumex pallidus						X				
Caryophylaceae										
Arenaria capillaris										P
Arenaria nardifolia							X			
Arenaria peploides	XXX									
Arenaria physodes						XX	XX			P
Cerastium beeringianum							XX			
Lychnis apetala								XXX		
Melandrium affine							XX			
Melandrium apetalum				XX						
Stellaria ciliatosepala										P
Stellaria crassifolia						XXX				
Stellaria edwardsii								XXX		
Stellaria humifusa		XXX								
Stellaria monantha							XXX			
Stellaria subvestita	XX							XX		
Ranunculaceae										
Anemone multifida										P
Anemone parviflora			XXX	XXX			XXX			P
Anemone richardsonii				XX						
Caltha natans					XXX					
Caltha palustris			XX				XX			P
Pulsatilla ludoviciana							XXX	P		P

Appendix A (continued)

Family - Species Zones:	1	2	3	4	5	6	7	8	9	10
Ranunculaceae (cont'd)										
Ranunculus gmelinii				P				P		
Ranunculus hyperboreus										P
Ranunculus lapponicus				P				P		
Ranunculus nivalis	X									
Ranunculus pallasii					XX					
Ranunculus pedatifidus				XXX						
Ranunculus reptans				P	P					
Ranunculus trichophyllus				XXXX	XXX					
Cruciferae										
Cardamine digitata				XXX				XXX	P	
Cardamine pratensis				XXX						
Cochlearia officinalis								XX		
Descurainia richardsonii						XX				
Descurainia sophioides						XXX	XXX	XX	XXXX	P
Draba cinerea								XXX		
Draba glabella							XXX	X	XX	
Draba hirta								P		
Erysimum cheiranthoides										P
Erysimum inconspicuum									XXX	P
Eutrema edwardii							XX	P		
Rorippa islandica										P
Rorippa sinuata						XX				
Sisymbrium salsugineum								XX		
Thellungiella salsuginea	X							X		

Appendix A (continued)

Family - Species	Zones: 1	2	3	4	5	6	7	8	9	10
Saxifragaceae										
Chrysosplenium tetrandrum					XX		XX			
Parnassia kotzebuei				XX			XX			
Parnassia palustris			P			XXX				P
Saxifraga cernua					XX					
Saxifraga hirculus				XX	XX			XX		
Saxifraga reflexa							XXX		XXX	P
Saxifraga tricuspida										P
Rosaceae										
Dryas integrifolia				XX			XXX	XXXX		
Fragaria glauca										P
Potentilla egedii		XXX								
Potentilla fruticosa				XX			XX			
Potentilla nivea									XX	
Potentilla pacifica						P				
Potentilla palustris				XXX						P
Potentilla pulchella		XX								
Potentilla rubricaulis								XX		
Rosa acicularis							XX			
Rubus chamaemorus							XXX			
Spirea beauverdiana										X
Leguminosae										
Astragalus alpinus		XX	XX							P
Astragalus richardsonii								P		
Astragalus yukonis										P

Appendix A (continued)

Family - Species Zones:	1	2	3	4	5	6	7	8	9	10
Leguminosae (cont'd)										
Hedysarum alpinum				XXX		XX				P
Hedysarum mackenzii										P
Lupinus arcticus				VA			VA			
Oxytropis arctica								XX		
Oxytropis campestris								XXX		P
Oxytropis hyperborea										P
Oxytropis maydelliana		XX						P		
Oxytropis viscida								P		
Linaceae										
Linum lewisii										P
Callitrichaceae										
Callitriche autumnalis				X						
Empetraceae										
Empetrum nigrum			XX				XXX	XXX		
Shepherdia canadensis										P
Onagraceae										
Epilobium angustifolium							XX		XXXX	
Epilobium latifolium									XX	
Epilobium palustre						P				
Haloragaceae										
Myriophyllum exalbescens				XX						
Hippuridaceae										
Hippuris vulgaris		X	XXX	XXXX	XXXX					P
Umbilleiferae										
Bupleurum americanum									X	
Conioselinum cnidiifolium				XXX	XXX	XXX				P

Appendix A (continued)

Family - Species	Zones:	1	2	3	4	5	6	7	8	9	10
Pyrolaceae											
Pyrola grandiflora		X						XXXX	XX		
Ericaceae											
Andromeda polifolia								XX			XX
Arctostaphylos rubra					XX		XX	XXX			
Cassiope tetragona								XXX	XXXX		
Ledum decumbens								XXX	XXX		
Rhododendron lapponicum					X			X			XX
Vaccinium uliginosum					X			X			XX
Vaccinium vitis-idaea					XX			XXX	XXX		
Primulaceae											
Androsace chamaejasme								XXX	XXX		
Primula borealis			X	XX	XXX						
Primula stricta											P
Plumbaginaceae											
Armeria maritima								X			
Gentianaceae											
Gentiana propinqua								XX			
Gentiana richardsonii			X	XX							
Lomatogonium rotatum			XX	XXX							
Polemoniaceae											
Polemonium boreale											P
Polemonium pulcherrimum										XXXX	
Boraginaceae											
Mertensia maritima		XX									

Appendix A (continued)

Family - Species	Zones:	1	2	3	4	5	6	7	8	9	10
Scrophulariaceae											
Castilleja pallida							X	XXX		XXX	P
Castilleja raupii									XX		
Pedicularis arctica					XXX			XXX	XXX		
Pedicularis capitata								XXX			P
Pedicularis labradorica											P
Pedicularis lanata									XXX		
Pedicularis sudetica								XXX	XX		P
Plantaginaceae											
Plantago eriopoda				XX							
Plantago septata			XX	XX							P
Rubiaceae											
Galium boreale											P
Compositae											
Achillea lanulosa											P
Achillea nigrescens			XX				XX				
Agoseris cuspidata										X	P
Arnica alpina						XXX					
Artemesia frigida										XXXX	
Artemesia tilesii		XXX					XX		XX	VA	P
Aster sibericus							XX				
Aster pygmaeus				XX			XX				
Chrysanthemum arcticum			XX								
Erigeron compositus											P
Erigeron glabellus											P

Appendix A (continued)

Family - Species	Zone: 1	2	3	4	5	6	7	8	9	10
Compositae (cont'd)										
Matricaria ambigua		XX				XX				P
Petasites frigidus							XXX		XXX	
Saussurea angustifolia										P
Senecio atropurpureus				X			XX	XX		P
Senecio congestus		XX				XXXX				P
Senecio hyperborealis										P
Senecio lugens							XX	XX	XX	P
Solidago multiradiata									XX	
Taraxacum sp.							X			
Mosses										
Calliergon giganteum				XXXX						
Drepauocladus aduncus					P					
Drepauocladus vernicosus					P					
Tomenthypieum intens					P					

Appendix B

Birds of the Anderson River Delta
Fort Anderson to Liverpool Bay

(See also MacFarlane, 1891, and Höhn, 1959)

Common Loon (Gavia immer). Rarely seen in upstream lakes.

Yellow-billed Loon (Gavia adamsii). Casual observations in Anderson River, Wood Bay and Liverpool Bay, probably of migrants and non-breeders. Common nester on Banks Island, although I doubt it nests on the mainland.

Arctic Loon (Gavia arctica). Common nester on the larger lakes of middle and inner delta and upstream south of tree line. Also on the larger lakes of the ptarmigan willows.

Red-throated Loon (Gavia stellata). Common nester in the smaller marshy lakes and sloughs of the inner and middle delta and ptarmigan willows. Less common south of the tree line.

Whistling Swan (Olor columbianus). Common nester on the marshy plains or lake edges of the middle and inner delta and ptarmigan willows. Rarely nests inside the tree line. Birds reported from The Forks and Crossley lakes are mostly non-breeders. Reports of very large swans in this area might be trumpeter swans (O. buccinator).

White-fronted Goose (Anser albifrons). Common nester of the inner delta, ptarmigan willows, river islands, lakes and tributary streams. Molts in large numbers on lakes of the inner delta and larger river channels. Less common inside tree line.

Snow Goose (Chen caerulescens). Common colonial nester of the middle delta. Molting flocks found in prairie part of delta, mouths of tributary streams, and Wood Bay beaches to Mason River delta. Blue goose (color phase): one mated to a snow goose in 1963, 1964, 1965, and a few seen each spring with snow geese in migration to Banks Island.

Ross' Goose (Chen rossii). Some probable observations with migrating snow geese to Banks Island where some nest.

Lesser Canada Goose (Branta canadensis parvipes). An uncommon nester along tributary streams (Nugluk Creek) and river islands. More common along river inside tree line.

Pacific Brant (Branta bernicla nigricans). Common colonial nester of outer delta and occasionally on islands in the lakes of middle and inner delta. During molt, found on mud flats, Wood Bay beaches and at mouths of tributary streams.

Mallard (Anas platyrhynchos). Fairly common nester in marshy prairie of inner delta.

Pintail (Anas acuta). Widespread nester in nearly all parts of the delta.

American Widgeon (Baldpate) (Mareca americana). Abundant nester in inner delta near channels and sloughs, and upriver. Males form large flocks with pintails on sandy river islands and potamogeton beds. Probably the most common duck in the delta.

Green-winged Teal (Anas carolinensis). Casual nester in the inner delta.

Canvasback (Aythya valisineria). Scarce nester in the inner delta. Large flocks of molting males seen at Crossley Lakes, west of old Fort Anderson.

Greater Scaup (Nyroca marila). Common nester near sloughs of the inner delta and the lakes of the ptarmigan willows. Molting males gather on a lake near Husky Bend, and in some seasons in surprisingly large numbers on Wood Bay with old squaws and scoters.

Common Golden-eye (Bucephala clangula). Wandering post-nuptial males seen on White-front Lake of inner delta and on main river channel.

Old Squaw (Clangula hyemalis). Common nester in the outer and middle delta and parts of the inner delta. Colonial with arctic terns on the south end of Study Area Island. Also nests in larger lakes along the coast and on Nicholson Island. Molts in large flocks along the Wood Bay beaches near Mason River, the southeast sands-pit of Nicholson Island, and the new Squaw Duck Channel between Nicholson and the mainland.

Common Eider (Somateria mollissima). Very rare nester in middle delta; one nest found in 1963. A starving male was picked up in the river in 1964, and a few males were observed near Harrowby Bay and Baillie Islands.

King Eider (Somateria spectabilis). A casual nester in the outer and middle delta. Huge numbers migrate past Cape Dalhousie and Baillie Islands. In seasons of complete sea-ice cover, like 1964, thousands have starved. Primary nesting area is on Victoria and Banks Island.

White-winged Scoter (Melanitta deglandi). Widespread nester in the lakes of the ptarmigan willows. A considerable number molt in Wood Bay.

Surf Scoter (_Melanitta perspicillata_). Not seen north of tree line except males in molting flocks with white-winged scoters and old squaws.

Common Scoter (_Oidemia nigra_). Rarely seen with other scoters especially post-nuptial males in Wood Bay and main river channel.

Red-breasted Merganser (_Mergus serrator_). An uncommon nester long the river and the coast. Scattered molting birds most often seen along Liverpool Bay coast between Nicholson Island and Smoke River.

Rough-legged Hawk (_Buteo lagopus_). Nests on cliffs and bluffs from Windy and Husky Bend north, and along Liverpool Bay and Mason River. In 1962 a pair nested in the bell tower of the abandoned mission church at Stanton.

Golden Eagle (_Aquila chrysaetos_). Established nest sites are regularly used in alternate seasons. Known nests at Husky Bend, South Bluffs, Mason River, and several along south shore of Liverpool Bay.

Bald Eagle (_Haliaeetus leucocephalus_). Nests sparingly along the river inside the tree line. I have only two observations of them north of tree line.

Gyrfalcon (_Falco rusticolus_). Nests on cliffs at Husky Bend and in trees upstream. Also nested on bluffs north of Stanton. Gray phase usually seen, but one white phase is known to have been caught at Nicholson airstrip. Every September three young vie for the top of our two radio masts, and the loser gets the cabin roof.

Peregrine Falcon (Falco peregrinus). Regular nester on the bluffs and cliffs of the Anderson River valley. The nest on South Bluffs has been reused every year of the study. The nest at Mason River is occupied every season we visited it.

Pigeon Hawk (Falco columbarius). One or two observations each year. A wanderer north of tree line, south of which it nests.

Sparrow Hawk (Falco sparverius). One male spent most of a day around the radio mast in 1961.

Marsh Hawk (Circus hudsonius). Regular but uncommon nester in ptarmigan willows and inner delta. About two pairs can be counted each season.

Willow Ptarmigan (Lagopus lagopus). Very common but in fluctuating numbers on ptarmigan willows and hilltops and along levees of channels. Abandons the delta for tree line in winter.

Rock Ptarmigan (Lagopus mutus). Reportedly nests on the higher parts of Nicholson Island. I have only two observations, however.

Little Brown Crane (Grus canadensis). Occasional nester in hilly country of ptarmigan willows and on dry ridges of the inner delta. One molting adult was captured swimming in 10 feet of water about 1/2 mile from the shore of a lake.

Whooping Crane (Grus americana). Höhn mentions, and I have heard several other reports of, two being seen in the inner delta in 1949.

Ringed Plover (Charadrius hiaticula). Scattered nester along gravelly beaches of Wood Bay and river channels and islands.

Killdeer (Charadrius vociferus). One observation in the middle delta; the bird stayed for two days.

Golden Plover (<u>Pluvialis dominica</u>). Nests scattered on the tops of rolling hills and South Bluffs.

Black-bellied Plover (<u>Squatarola squatarola</u>). Nests sparingly on the low ridges amid the inner delta's marshy prairies.

Ruddy Turnstone (<u>Arenaria interpres</u>). Observed only as a migrant in late May and early June during only three seasons.

Wilson's Snipe (<u>Capella gallinago</u>). Fairly common nester in ptarmigan willows and in willows on levees of inner delta.

Whimbrel (Hudsonian Curlew) (<u>Numenius phaeopus</u>). Fairly common nester on dry hummocks of the marshy prairie of the inner delta.

Eskimo Curlew (<u>Numenius borealis</u>). Four possible observations during the period 1960 to 1965. The most convincing observation was on the shore of Bipsi Lake in 1961; one bird was in a flock of whimbrels and golden plovers. MacFarlane said it bred abundantly in this region 100 years ago.

Spotted Sandpiper (<u>Actitis macularia</u>). Nests fairly commonly upstream from Husky Bend inside tree line. Rarely seen north of tree line.

Lesser Yellowlegs (<u>Totanus flavipes</u>). Scarce nester in the inner delta, more abundant south of the tree line.

Greater Yellowlegs (<u>Totanus melanoleucus</u>). One pair with four young were found by Dr. Cyril Hampson nesting under <u>Salix alaxensis</u> in the inner delta in 1963. This is a considerable northward range extension.

Pectoral Sandpiper (<u>Erolia melanotos</u>). Very common nester in the marshy areas of the middle and inner delta.

White-rumped Sandpiper (<u>Erolia fusciollis</u>). Rare nester, seen at Kettle-hole Point and Nicholson Island, as well as along the coast.

Baird's Sandpiper (Erolia bairdii). Observed only as a fairly common spring migrant in late May and early June.

Long-billed Dowitcher (Limnodromus scolopaceus). Rare nester in inner delta in grassy marsh near scrub willow.

Stilt Sandpiper (Micropalama himantopus). Fairly common nester in wet areas of ptarmigan willows, middle delta and inner delta.

Semipalmated Sandpiper (Ereunetes pusillus). Most abundant shore bird; found nesting throughout the delta.

Western Sandpiper (Ereunetes mauri). Rare spring migrant.

Least Sandpiper (Erolia minutilla). Seldom seen and then inside the tree line only.

Buff-breasted Sandpiper (Tryngites subruficollis). Uncommon nester on hilltops and dry grassy areas of inner delta.

Bar-tailed Godwit (Limosa lapponica). One observation in middle delta of bird in fall plumage.

Hudsonian Godwit (Limosa haemastica). Fairly common nester in or near dry grass meadows, next to willows or the higher timber, if inside the tree line. Very noisy around nest.

Sanderling (Crocethia alba). Observed as an early August migrant on Wood Bay and Liverpool Bay.

Red Phalarope (Phalaropus fulicarius). Post-nesting stragglers seen in small lakes of the middle delta in late June and July, probably females still in breeding plumage.

Northern Phalarope (Lobipes lobatus). Common nester around the sloughs and marshes of the middle and inner delta.

Pomarine Jaeger (Stercorarius pomarinus). Migrant, fairly common in loose flocks between June 9 and 13.

Parasitic Jaeger (Stercorarius parasiticus). Nests, widely scattered, on dry mud flats or short grass of outer, middle and inner delta. A relentless egger.

Long-tailed Jaeger (Stercorarius longicaudus). Usually seen as a migrant in mid-June. Some nest widely scattered in the uplands of ptarmigan willows.

Glaucous Gull (Larus hyperboreus). Colony nester on Gull Island and other high spots of the outer delta. Others nest on high islets in lakes of the inner delta, still others on gravel islands of Mason River delta.

Thayer's Gull (Larus thayeri). Gulls of this type were observed as stragglers; presumed to be Thayer's, not herring gulls. One specimen collected was a Thayer's.

Common (Mew) Gull (Larus canus). Nests fairly commonly inside the tree line. Stragglers usually observed feeding amid the debris carried by river break-up ice, and later as post-nesting wanderers to the shores of Wood Bay.

Bonaparte's Gull (Larus philadelphia). Fairly common nester in spruce from Husky and Windy Bend upstream. Never seen north of tree line.

Sabine's Gull (Xema sabini). Observed mostly as a migrant in spring, but regular summer observations make me suspect it is a scarce but regular nester in the middle delta and Mason River delta.

Arctic Tern (Sterna paradisaea). Fairly common nester in small colonies on outer and middle delta and on some sandy river islands.

Snowy Owl (Nyctea scandiaca). Winter resident; only a few spring migration observations and one summer record.

Hawk Owl (Surnia ulula). Four observations of this bird on the radio mast, a straggler north of tree line. Very tame.

Short-eared Owl (Asio flammeus). Fluctuating numbers from rare to very abundant. Nests in ptarmigan willows and ridges of the inner delta. Has an uncanny ability to appear only in years the vole, Microtus economus, is super-abundant.

Yellow-shafted Flicker (Colaptes auratus). Nests within tree line. One straggler seen flying north over Wood Bay.

Hairy Woodpecker (Dendrocopus villosus). Several observations of them feeding among Salix alaxensis along tributary streams and where snow drifts foster taller willow growth.

Say's Phoebe (Sayornis saya). First found nesting by Patricia S. Barry in an abandoned cabin at Stanton in 1959. One or two pairs have nested in the abandoned buildings of Stanton every season since.

Horned Lark (Eremophila alpestris). Uncommon migrant and rare nester in ptarmigan willows. More common on dry hilltops and on Nicholson Island.

Bank Swallow (Riparia riparia). Nests on low silty banks of river islands near Fort Anderson.

Barn Swallow (Hirundo rustica). Three tried to get in under the eaves of the cabin one day in 1958.

Cliff Swallow (Petrochelidon pyrrhonota). Builds mud nests on protected rock cliffs upstream near The Forks. Several seen around the cabin as stragglers beyond tree line.

Canada Jay (Perisoreus canadensis). An occasional post-nesting straggler beyond tree line. Common within the timber.

Magpie (<u>Pica pica</u>). One was shot at Cape Parry, out of range of this list, but nevertheless a northern record worth noting.

Common Raven (<u>Corvus corax</u>). Fairly common, probably nests on cliffs of Husky and Windy Bend inside the tree line. It is often possible to detect the presence of a grizzly bear or wolf by behavior of ravens.

Boreal Chickadee (<u>Parus hudsonicus</u>). Nests within tree line and never seen further north.

Robin (<u>Turdus migratorius</u>). Nests in the larger willows along channels and river bank. More common inside tree line.

Gray-cheeked Thrush (<u>Hylocichla minima</u>). Uncommon in thicker willows along tributary streams and river and into timbered areas.

Wheatear (<u>Oenanthe oenanthe</u>). One observed at South Bluffs in 1963.

Water Pipit (<u>Anthus spinoletta</u>). Common nester only at South Bluffs and Stanton Bluffs, etc.

Bohemian Waxwing (<u>Bombycilla garrula</u>). Nests within the tree line; rare straggler beyond.

Northern Shrike (<u>Lanius excubitor</u>). Found nesting near Old Fort Anderson, but not seen north of tree line.

Starling (<u>Sturnus vulgaris</u>). This is their first record of reaching the Arctic Coast; five were seen on the cabin roof May 21, 1963. They flew northeast over Wood Bay. Three birds, presumably the same, returned May 31 after a snow storm.

Yellow Warbler (<u>Dendroica petechia</u>). Rather scarce nester in taller willows along tributary streams and channels.

Myrtle Warbler (<u>Dendroica coronata</u>). Scarce nester from Windy Bend upstream.

Blackpoll Warbler (Dendroica striata). Uncommon nester in spruce from Husky Bend upstream.

Rusty Blackbird (Euphagus carolinus). Nests in willow thickets from inner delta (rarely) and upstream. Usually seen in ptarmigan willows in spring and fall migration.

Hoary Redpoll (Acanthis hornemanni). Common nester in ptarmigan willows, especially near river bank.

Common Redpoll (Acanthis flammea). Common nester in ptarmigan willows, especially among taller willows of river bank.

Savannah Sparrow (Passerculus sandwichensis). Common nester in ptarmigan willows, especially in grassy clearings.

Slate-colored Junco (Junco hyemalis). Nests uncommonly inside the tree line. Never seen north of Husky Bend.

Tree Sparrow (Spizella arborea). Common nester in ptarmigan willows; nest usually near base of a willow clump.

Harris' Sparrow (Zonotrichia querula). Nests within the tree line. One of the commonest sparrows in the timbered part of the valley from Husky Bend upstream. Never seen beyond tree line. It is surprising MacFarlane did not mention it 100 years ago.

White-crowned Sparrow (Zonotrichia leucophrys gambelii). Probably the most common sparrow of the ptarmigan willows.

Fox Sparrow (Passerella iliaca). Fairly common nester in timber and thicker willows of the inner delta. Rarely nests among thick willows of the river bank itself, but is a common straggler north to the cabin area.

Lapland Longspur (Calcarius lapponicus). Very abundant on drier part of middle and inner delta, ptarmigan willows and hilltops, where-ever there are open willows or grass. Aerial courtship song is heard almost continuously in the vicinity of snow goose nests.

Snow Bunting (Plectrophenax nivalis). Spring migrant, often with longspurs. May nest in old log-covered graves or driftwood of Wood Bay. There are no other suitable sites in the vicinity.

Appendix C

Mammals of the Anderson River Delta
Fort Anderson to Liverpool Bay

Tundra Shrew (_Sorex tundrensis_). Common around cabin and on ptarmigan willows. Usually caught in winter in our refrigerator hole (fuel drums sunk in the permafrost). Quick to eat the head and neck of voles caught in snap traps.

Black Bear (_Ursus americanus_). Rare in the delta area. Most often seen upstream in the vicinity of The Forks and beyond.

Barren-Ground Grizzly Bear (_Ursus horribilis_) (_Ursus inopinatus_, separate species?). Common in the delta area, most often seen along the main channels and the south shore of Liverpool Bay. Appear to wander great distances, and occasionally get onto the goose nesting islands in the delta. Females with two cubs most frequently seen. One with three cubs observed. From one to 30 seen per season. Caused considerable damage to house in fall of 1964 and of 1965.

Polar Bear (_Thalarctos maritimus_). Tracks seen on Wood Bay beaches in 1958 gave good comparison to grizzly bear tracks seen in same spot. Common on Baillie Islands.

Marten (_Martes americana_). Reported as far north as Nicholson Island but is usually an inhabitant of the tree line. It is the number one fur bearer of the timbered areas upstream.

Least Weasel (_Mustela rixosa_). Rarely seen. One dead specimen found in ptarmigan willows. There is evidence they harass bush and ground-nesting passerines.

Short-tail Weasel (Mustela erminea). Sometimes encountered among driftwood piles along the main river channel. Very abundant (up to 14 seen) around the cabin in 1963 when the vole population was exceptionally high in the ptarmigan willows.

Mink (Mustela vison). Encountered following the channels and tributary streams of the inner delta and upstream.

Wolverine (Gulo luscus). A wide-ranging wanderer, but seldom seen north of tree line after break-up. One specimen taken in the inner delta had been feeding on pintail drakes, probably molters.

River Otter (Lutra canadensis). One or two observed on outlet streams that form the headwaters of the Smoke River, 69°N are probably the northern records for this species.

Red Fox (Vulpes fulva). Common in the ptarmigan willows, but never seen in the delta after break-up. Three observations of the black phase on Wood Bay beaches and a tributary stream.

Arctic Fox (Alopex lagopus). Common. Den in the middle delta occupied for several seasons. Arctic foxes seem to prefer the low vegetation of the delta, Wood Bay beaches and Nicholson Island.

Gray Wolf (Canis lupus). Common. Tracks of individuals are recognizable along the main channel and beaches. Gray phase most common, then black; one extremely large white phase wolf was seen.

Lynx (Lynx canadensis). Not seen north of tree line. Fairly common, but in fluctuating numbers, from Husky and Windy Bends on upstream.

Ringed Seal (Phoca hispida). Common in the tide rips at the north sandspit of Mason River delta, the southeast sandspit of Nicholson Island, and the newly-formed Squaw Duck Channel that separates Nicholson Island from the mainland.

Bearded Seal (Erignathus barbatus). Nearly every season as many as four bearded seals come into the delta as far as the channels of the inner delta, and pull out to rest on gravelly or sandy beaches or on hard turf near deep water. Reason for the presence of this so-called seal of the floe-edge in Anderson River Delta as well is the other deltas and bays of Liverpool Bay is a mystery.

Walrus (Odobenus rosmarus). About once every four or five years a Pacific walrus is shot at Banks Island or Baillie Islands.

Arctic Ground Squirrel (Citellus parryi). Common on the south or southwest facing slopes, river banks, tributary streams or bluffs. Appears to be an important grizzly bear food.

Red Squirrel (Tamiasciurus hudsonicus). Rare to fairly common from the spruce stands at Husky Bend on upstream.

Beaver (Castor canadensis). Rare, but an active bank house was located in a lake off the tributary stream by Jacobson's cabin 69°35'N, probably a northern record. On three occasions beaver have followed the break-up out to Wood Bay. From the number of old cuttings found among the driftwood in Wood Bay, it appears they were once more abundant in the river valley.

Brown Lemming (Lemmus trimucronatus). Neither seen nor trapped.

Greenland Collared Lemming (Dicrostonyx groenlandicus). Fairly common on the middle delta and on Nicholson Island. Not subject to large fluctuations in numbers.

Meadow Vole (Microtus pennsylvanicus). Neither seen nor trapped.

Tundra Redback Vole (Clethrionomys dawsoni). Neither seen nor trapped.

Tundra Vole (Microtus oeconomus). Very abundant, but in fluctuating numbers in the grass and sedge stands of ptarmigan willows, Wood Bay beaches, and the middle and inner delta. Their population changes seem to be accurately predicted by the short-eared owls.

Yellow-cheeked Vole (Microtus xanthognathus). Neither seen nor trapped.

Muskrat (Ondatra zibethica). Fairly common along the channels of the inner delta and oxbow lakes and snyes upstream. In 1962-1963, a period of peak abundance, they were seen regularly along the main channel as far north as Wood Bay.

Porcupine (Erethizon dorsatum). Very rare; reported from upstream near The Forks.

Arctic Hare (Lepus arcticus). No known reports from this area of the mainland. I doubt it exists on the coastal plains, but possibly it does occur in the pre-Cambrian areas further east.

Snowshoe Hare (Lepus americanus). Common in fluctuating numbers in the river and lakeshore willows upstream from Husky Bend.

Moose (Alces americana). Common in summer on the delta and beaches. Usually yearling bulls, seeking to get free of insects. In winter, moose are occasionally seen browsing on river willows in the Anderson, Moose, Mason and Smoke rivers, well beyond tree line. Recorded as far north as Bathurst Peninsula (Baillie Islands).

Barren-Ground Caribou (Rangifer arcticus). Common in the delta and on beaches usually beginning in late June when they move into the area from the northeast. Some stray reindeer undoubtedly occur also. A large migration up the Anderson River, usually the east side, occurs in late October and November.

Muskox (Ovibos moschatus). Part of a skull was found near Stanton. Muskox probably formerly occupied all of Bathurst Peninsula (Bodfish, 1937). Nearest known herd is in the vicinity of the upper Hornaday and Horton rivers, about 125 miles southeast of the Anderson River Delta.

Bowhead Whale (Balaena mysticetus). Fairly common off Atkinson Point, Cape Dalhousie and Baillie Islands. Remains of stranded bowhead on Campbell Island, deep in Liverpool Bay.

Pacific Killer Whale (Grampus rectipinna). Three reported in Liverpool Bay in 1962. Several other reports from along the Arctic Coast from Baillie Islands to Herschel Island.

White Whale (Delphinapterus leucas). Fairly common in Liverpool Bay and especially at Baillie Islands. Some, probably following the herring runs, have blundered into the innermost of the Eskimo Lakes where approximately 30 were trapped at freeze-up in 1966-67.

Appendix D

Helminths of Geese, Anderson River Delta, N.W.T., 1961
By John Holmes, University of Alberta

	Snow Geese						Pacific Brant						White-fronts		
	18 Adults			13 Young*			10 Adults			7 Young*			8 Adults		
	% Inf.	M Mean	Max	% Inf.	M Mean	Max	% Inf.	M Mean	Max	Inf.	M Mean	Max	% Inf.	M Mean	Max
Gizzard nematodes:															
Amidostomum spatulatum	83	5.6	20		0			0		29	1.0	1	75	4.7	13
A. acutum	6	1.0	1		0			0			0			0	
Epomidiostomum crami	100	6.6	16		0		100	7.2	15		0		100	13.0	26
Intestinal & caecal nematodes:															
Capillaria caudinflata	72	4.0	19	23	5.7	10	20	9.0	17	100	19.1	56		0	
Heterakis sp.	39	1.2	2	15	1.0	1	60	23.7	99	100	19.0	32		0	
Trichostrongyloidea gen. sp.		0			0			0			0		13	1.0	1
Caecal trematodes:															
Notocotylus attenuatus	28	2.4	7	15	2.5	3		0		14	2.0	2	50	2.5	6
Zygocotyle lunatum	6	2.0	2		0			0			0			0	
Intestinal cestodes:															
Fimbriaria fasciolaris	83	7.8	33	100	40.4	132	100	68.3	157	100	258	545	63	13.2	25
Drepanidotaenia lanceolata					X										
Hymenolepis setigera		X			X						X				
Hymenolepis spp.		X			X			X			X			X	

X=Present. *Two to three weeks old.

Note: On Banks Island in 1961 the number of cestodes in 3-week-old snow geese ranged from 500 to 850, much higher than in Anderson River Delta birds.

Figure 68. Outdoor laboratory; collecting parasites.
(Sam Barry, Patricia Barry, John Holmes.)

Appendix E

Species of Carabides (Coleoptera) Collected in the Anderson River Delta by George Ball (1963) University of Alberta

1. *Carabus chamissonis* Fischer von Waldheim
2. *Elaphrus americanus* Dejean
3. *Bembidion lenae* Csiki
4. *Bembidion bimaculatum* Kirby
5. *Pterostichus nearcticus* Lindroth*
6. *Pterostichus arcticola* Chaudoir
7. *Pterostichus tareumiut* Ball
8. *Pterostichus barryorum* Ball*
9. *Pterostichus stantonensis* Ball*
10. *Pterostichus caribou* Ball
11. *Pterostichus brevicornis* Kirby
12. *Pterostichus mandibularoides* Ball*
13. *Pterostichus haematopus* Dejean
14. *Agonum exaratum* Mannerheim

*Type locality - Anderson River Delta.